Sky and TELESCOPE

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OCTOBER, 1954

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International Astronomical Union Meetings

THE executive committee of the International Astronomical Union decided at its July meeting in Liége, Belgium, that the ninth general assembly in Dublin, Eire, is to take place from August 29 to September 5, 1955.

There will be two general symposia — one on a comparison of the large-scale structure of our galaxy with that of other galaxies, and the other on nonstable stars. The former will be organized by a committee under J. H. Oort, and the latter by a committee under V. A. Ambarzumian, P. Swings, and G. H. Herbig. There will also be four joint discussions, turbulence in stellar atmospheres, fundamental stars, solar flares, and image converters, each under the auspices of several standing commissions.

The executive committee discussed invitations for the 1958 general assembly from Belgium, the Soviet Union, and Poland, together with tentative invitations previously received from Argentina, South Africa, and Australia. The committee unanimously decided that it viewed with favor the invitation to Moscow in 1958, and instructed the general secretary to investigate with vice-president Ambarzumian the possibility of making all the necessary arrangements.

The undersigned read a letter from the assistant secretary of state and requested that the executive committee place on its books a tentative invitation to meet in the United States in 1961. He underlined the fact that this invitation would be made formal only if the United States government would see its way to meet the essential requirement that all competent astronomers who are members of the International Astronomical Union would be welcome. This invitation was supported by the U.S. National Committee on Astronomy, by the National Research Council, and by the American Astronomical Society. The executive committee "unanimously decided to record that it is grateful for and interested in the invitation from the U.S.A. for a meeting in 1961."

Two new countries were admitted to the union, Venezuela and Israel. Several other countries are in the process of forming suitable organizations for affiliation in 1955.

OTTO STRUVE, president
International Astronomical Union

AMERICAN members who wish to attend the Dublin meeting of the IAU are asked to notify the undersigned before February 1, 1955. The National Science Foundation will make grants in partial support of traveling expenses to Dublin for a limited number of persons. Application forms may be secured from the National Science Foundation, Washington 25, D. C., and should be filed at the NSF office before December 1st.

At Manchester, England, a symposium will probably take place on August 25-27, on the occasion of the dedication of the 250-foot Jodrell Bank radio telescope. Two other symposia are planned after the Dublin meeting, not under the IAU, one at Hamburg-Bergedorf, West Germany, at the time of the dedication of the large Schmidt telescope, and the other at Liége, Belgium, on band spectra.

J. J. NASSAU, chairman
U. S. National Committee, IAU
Warner and Swasey Observatory
East Cleveland 12, Ohio

VOL. XIII, NO. 12 OCTOBER, 1954

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COVER: The radio telescope at Harvard Observatory's Agassiz station at Harvard, Mass. The 25-foot mirror, constructed by the D. S. Kennedy Company, is mounted equatorially. The funds for the equipment were provided by the National Science Foundation and by an anonymous friend of the observatory. This photograph was taken in the summer of 1954 by Walter R. Fleischer, of the Harvard University news office. (See page 408.)

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THE INDEX TO VOLUME XIII

of *Sky and Telescope* is included in the center of this issue. It may be removed for binding purposes by opening the staples. Indexes to Volumes I through IX are available, at 35 cents each postpaid. The indexes since Volume X appear in each October issue.

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SKY PUBLISHING CORPORATION
Harvard College Observatory
Cambridge 38, Massachusetts

Radio Studies of Interstellar Hydrogen

By Bart J. Bok, *Harvard College Observatory*

THE DISCOVERY of radio radiation from neutral hydrogen of the Milky Way took place in March, 1951. As early as 1944, H. C. van de Hulst, of Leiden, had suggested that neutral hydrogen atoms in interstellar space might emit detectable radiation with a wave length of 21 centimeters, in the radio-microwave range. Then, in 1951, H. I. Ewen and E. M. Purcell, of the department of physics at Harvard University, succeeded in detecting the line as a radio noise signal from the Milky Way, a result that was confirmed shortly afterwards in Holland and in Australia. Only a little more than three years have elapsed since these first observations, but already "21-cm. research" has become a major field of astronomical activity.

We have already passed beyond the first stage, in which single spectacular discoveries are most of the story, to the next level, in which the radio technique has taken its place along with photographic, photoelectric, and spectrographic methods in the investigation of the structure and evolution of our own and other galaxies.

At the four radio observatories engaged principally in 21-cm. research, astronomers are concerned with four distinctly different groups of problems. At Leiden and Kootwijk, the Dutch group led by J. H. Oort and van de Hulst has worked primarily, and with amazing effectiveness, on problems related to the spiral structure of our galaxy. At the Agassiz station of Harvard Observatory, Dr. Ewen and myself and our associates, A. E. Lilley and D. S. Heeschen, have made regional studies of the 21-cm. radiation, with emphasis on the correlation between optical and radio phenomena. John P. Hagen and his co-workers at the Naval Research Laboratory in Washington, D. C., have dealt especially with the central regions of our galaxy and with associated radiation at wave lengths close to but outside that of the hydrogen line at 21 centimeters. The fourth group, the Australian radio astronomers at Sydney, has concerned itself most recently with the radiation reaching us from the two Magellanic Clouds.

Let us recapitulate briefly how the 21-cm. radiation originates. The neutral hydrogen atom consists of a positively charged nucleus, the proton, and an electron with an electrical charge of equal amount but negative sign. In the lowest level of excitation—the level in which practically all neutral hydrogen atoms in interstellar space exist — the electron's magnetic axis has a choice between two positions relative to the magnetic axis of the nuclear proton. The two axes can be either directed parallel to each other, with the spinning in the same direction for both, or they can be "antiparallel," that is, spinning in opposite directions.

In the case of parallel spins, the energy of the atom is slightly greater than for antiparallel spins. The 21-cm. radiation originates as an emission line if the hydrogen atom passes from the state of parallel to antiparallel magnetic axes of proton and electron; it is an absorption line if the atom absorbs enough energy in the antiparallel level of lowest energy to lift it to the parallel level of slightly higher energy.

One often hears quoted the frequency rather than the wave length of this spectrum line; for the 21-cm. line without Doppler displacement the frequency is 1,420 megacycles per second.

In Holland, Oort, van de Hulst, and C. A. Muller have measured 21-cm. radiation for positions at five-degree intervals in galactic longitude in an attempt to study the spiral structure of our own Milky Way system. It had been known for some time that ionized hydrogen, which contributes much to the optical radiation from the emission nebulae of the Milky Way, is concentrated in the spiral arms of our system and of the Great Nebula in Andromeda. Oort and his associates reasoned that it was likely that neutral hydrogen would show similar concentration and, hence, that they could hope to detect the spiral arms of our own Milky Way system from condensations of neutral hydrogen.

The results of the Dutch studies, in Fig. 1, seem to indicate clearly the presence of a spiral pattern. To understand how these dots and circles were obtained, inspect Fig. 2, which shows a typical 21-cm. scan made at Harvard's Agassiz station with the radio telescope shown on the front cover. The precise frequency at which each observation is made is plotted horizontally, against the recorded intensity at that frequency. Since the spectrum line from a neutral hydrogen atom at rest would be very sharp, all radiation from the Milky Way would be observed at one single frequency or wave length if there were no relative motions in the galaxy. However, the Milky Way rotates around its center, and this rotation is not of the solid-body variety. Hence the hydrogen clouds change their positions relative to one another and, as a consequence, have different radial motions with respect to the sun, depending on their relative positions in the Milky Way.

For any given direction in the plane of the galaxy, we know reasonably well what velocity of approach or recession

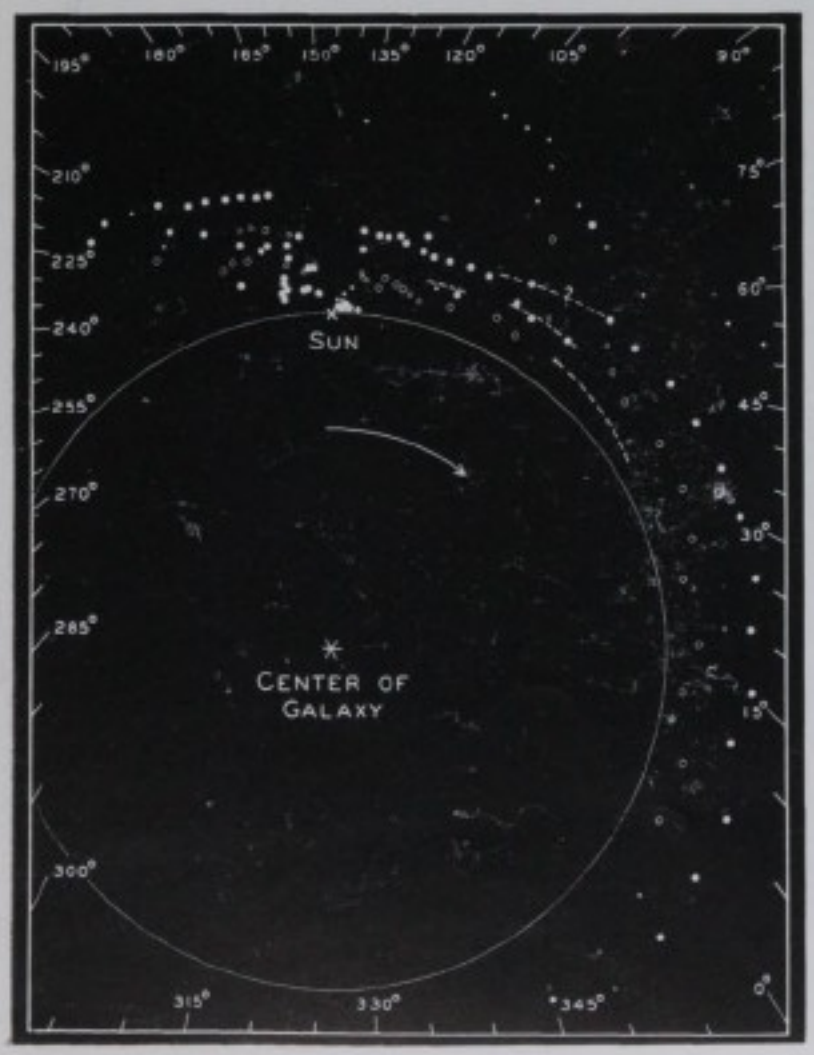

Fig. 1. The spiral structure of our galaxy, from observations by Dutch radio astronomers, is plotted on a scale of one centimeter to 2,300 parsecs. The plane of the galaxy lies in the paper, and the numbers are galactic longitudes. Large dots, marking maxima of hydrogen density, lie along the spiral arms; small dots indicate lesser maxima; and broken lines mark continuous sequences of maxima. The minima of hydrogen density (open circles) lie between the spiral arms. From the "Bulletin" of the Astronomical Institutes of the Netherlands.

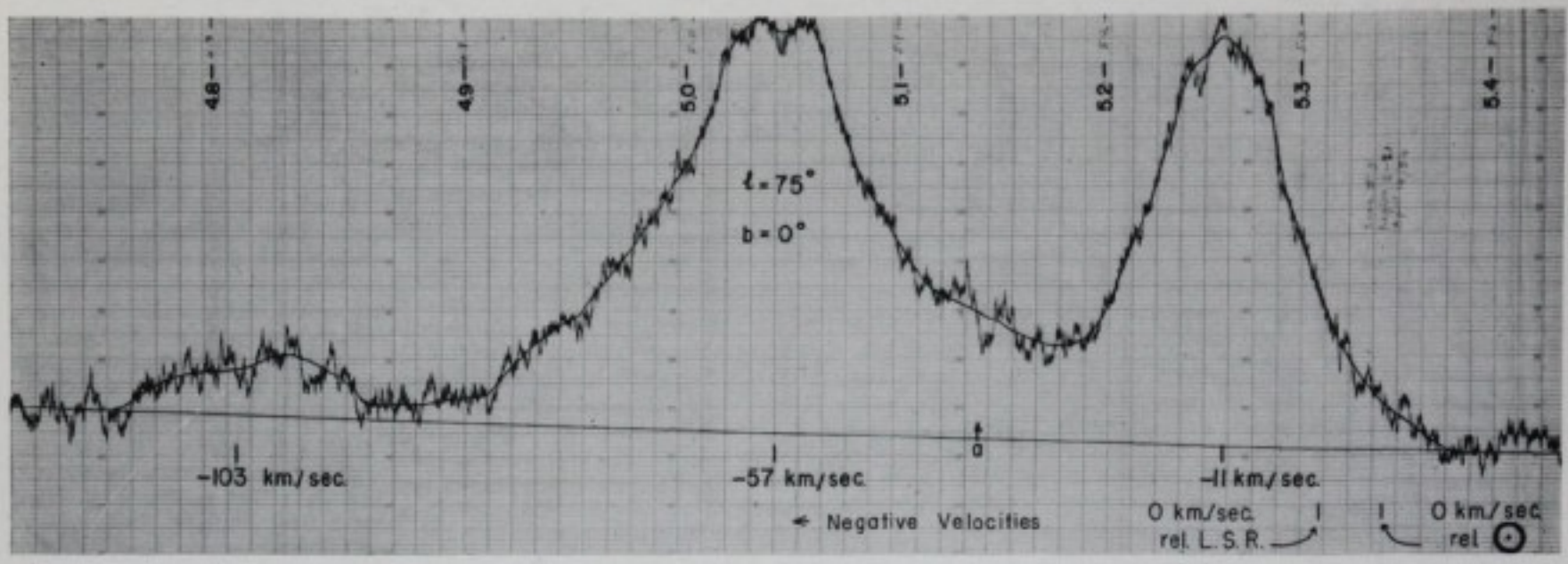

Fig. 2. A typical record of the profile of the 21-cm. hydrogen line, by T. A. Matthews. The vertical scale is intensity, and the horizontal scale is frequency, which at the same time is a measure of velocity of approach or recession.

to expect at any particular distance from the sun. Since — through the Doppler effect — the frequency at which the line is recorded will have been shifted to a shorter or longer wave length by an amount directly proportional to the velocity of approach or recession, we can from the observed frequency of any particular feature in the record deduce its velocity of approach or recession, and in turn estimate at what distance from the sun it is.

In Fig. 2 we observe three maxima, one very pronounced at a frequency corresponding to a velocity of approach of 11 kilometers per second (after correction for the sun's motion relative to nearby stars), the second corresponding to a velocity of approach of 57 kilometers per second, and the third, quite weak, to a velocity of approach of 103 kilometers per second. These three maxima presumably correspond to three distinct places where the spiral arms cross the line of sight of the radio telescope. The Dutch astronomers have analyzed curves such as Fig. 2 for many directions in the Milky Way, and thus they have produced the remarkable results of Fig. 1.

To appreciate the truly revolutionary aspects of Fig. 1, bear in mind that before the days of radio astronomy there seemed to be little hope, in studies of the spiral structure of our Milky Way, that we would ever be able to penetrate to distances much in excess of 10,000 light-years, about one third of the distance from the sun to the galactic center. In optical astronomy we are always bothered by the obscuring effects of cosmic dust close to the central plane of the Milky Way. Radio waves — at least those with wave lengths near 21 centimeters — pass almost undisturbed through the cosmic dust, and thus by radio methods we may indeed explore the whole of the Milky Way system, even the half beyond the center! Fig. 1 shows that the spiral features have actually been traced to twice the distance from us to the galactic center.

In recent months, Oort and his associates have turned their attention to the region of the galactic center. On some scans, similar to Fig. 2, they have found remarkable low but very broad extensions in frequency. These they attribute to relatively cool hydrogen gas with highly turbulent radial motions, located in the central bulge of the galaxy.

The distinctive feature of the radio telescope at Harvard is relatively high resolution in frequency, corresponding to a resolving power in radial velocity of three kilometers per second. Our equipment resembles a high-dispersion spectrograph working at radio frequencies. These features were built into our electronic apparatus by Ewen, and the equipment has been kept in tiptop operating condition by our electronics engineer, John A. Campbell.

At the Agassiz station, two regional surveys have been completed. In Lilley's survey, the central problem has been the determination of the ratio between the densities of gas and dust in a large complex of dark nebulae. We know from optical studies that, in an average sample of interstellar space, the dust particles (whose existence is known from their absorbing and reddening effects) probably account for less than one per cent of the total density of gas and dust taken together. Up to the present time, there has really been no way of deciding if this ratio is the same everywhere. In other words, we do not know if the relative amounts of dust and gas vary as we proceed from an average sample of interstellar space near the central Milky Way plane to an average spot inside a dust complex, in which the dust grains are at least 10 times more numerous. And what is this ratio in a very dense, small dark nebula in which the number of dust grains per unit volume may be 10 times greater still? Lilley's results prove conclusively that the neutral hydrogen gas density in a dark nebula complex is greater than in the surrounding galactic substratum, but there is as yet insufficient evidence to demonstrate certainly whether or not the dust and gas occur in equal proportions in the complex and in the substratum.

Lilley has concentrated on the anticenter, in Taurus and Auriga, the part of the Milky Way directly opposite in the sky to the center. The center section is in Sagittarius, Scorpius, and Ophiuchus. His principal results are illustrated by Figs. 3 and 4.

In Fig. 3, there are two plots in a single diagram. In one case, the vertical scale is peak brightness temperature; this is a measure of the height of a feature like one of the three maxima shown in Fig. 2, and it is also a significant measure of the total number of neutral hydrogen atoms along a line of sight. The black dots in Fig. 3 — through which Lilley has drawn the dashed curve — represent the variation of peak brightness with galactic latitude. For

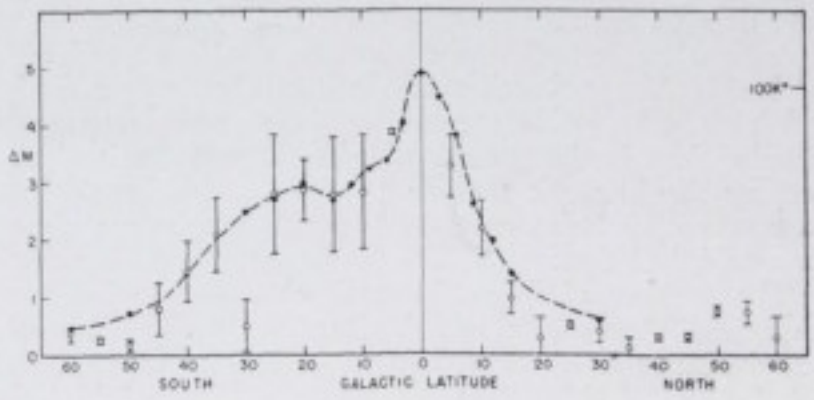

Fig. 3. A close association between interstellar dust and neutral hydrogen is shown in this plot for the anticenter region of the Milky Way. Hydrogen temperatures are shown by black dots; open circles are from earlier determinations of the dimming by cosmic dust.

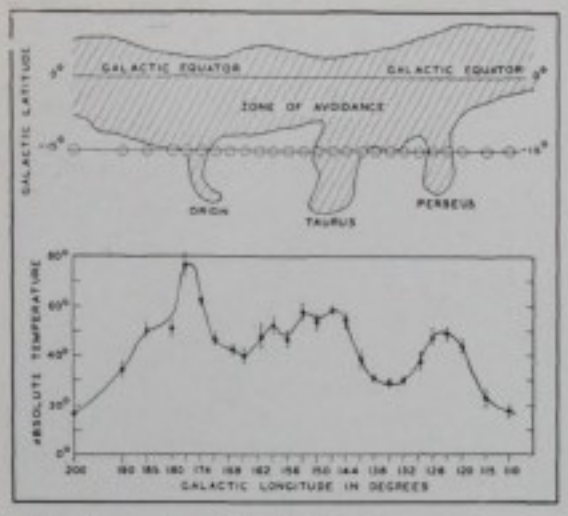

Fig. 4. The Milky Way from Perseus to Monoceros, as observed by optical techniques and the radio method. Above, the dust clouds are shown as charted by Hubble, from the blotting out of distant galaxies; below, 21-cm. observations along a belt at galactic latitude −15°. The circles in the upper part show the galactic longitudes at which the radio observations were made.

the second plot, on the vertical scale at the left are the total optical absorptions, in magnitudes of dimming, found from counts of faint galaxies made in 1933 by E. P. Hubble at Mount Wilson Observatory. The short horizontal lines show the two estimated absorptions as close to each radio position as Hubble's counts permit us to go, and the open circles indicate the assumed value at each galactic latitude.

This diagram shows clearly that to the north of the galactic plane the obscuration thins out rapidly and the peak brightness temperature drops, whereas south of the plane there is still considerable obscuration between galactic latitudes −20° and −40°, where the peak brightness temperature is also high. Where there is more dust, there are apparently also more neutral hydrogen atoms.

Fig. 4 gives further evidence on this score. The upper half of the diagram reproduces the boundaries of Hubble's zone of avoidance for the Milky Way between galactic longitudes 100° and 200°; the shaded portion indicates the part of the sky for which an absence of observed faint galaxies suggests very high total absorption. The circles mark where Lilley observed 21-cm. profiles, from which the peak brightness temperatures plotted in the lower graph were derived. Again there is good evidence that gas and dust go together. The present observations suggest that the dust is a somewhat larger fraction of the total gas plus dust inside the denser dark nebulae than in the general substratum, but we should await the results of future research before we can consider this an established fact.

The problem of fixing this ratio observationally must be solved, since it bears directly on the evolution of dark nebulae and globules. The evolutionary development — collapse into a star or otherwise — for a compact dark nebula will be very different for a cloud of dust grains without gas than for the same cloud with 100 grams of gas available for every gram of cosmic grains.

Fig. 5 shows the general character of the 21-cm. line profiles observed by Heeschen for the central region of the Milky Way, including the Ophiuchus dark complex. The center itself lies in a direction not far from galactic longitude 327°, galactic latitude 0° or −2°.5. Heeschen's first profiles (December, 1953) already exhibited clearly the double-humped appearance shown by some of the profiles in Fig. 5. This complex structure was puzzling, for toward the galactic center there should in general be no line of sight component of galactic rotation, regardless of distance. What, then, causes the multiple humps? Heeschen has advanced two possible working hypotheses.

In his first model, he assumes the presence of superimposed hydrogen clouds at different distances from the sun. The observed profiles could result from such clouds, whose radial velocities differ by about 10 kilometers per second. Heeschen notes that the curves for large galactic latitudes are all far simpler in appearance than for small galactic latitudes. He interprets this as caused by differences in the average distance of the two hydrogen cloud systems. The nearer of the two should obviously appear to have the greater extent in latitude.

Heeschen's second model calls for a region of relatively "cool" neutral hydrogen lying in front of the denser region of "hot" neutral hydrogen. The hot region may have a temperature of about 120° Kelvin, that is, −153° centigrade, whereas the cool region would measure 40° Kelvin or −233° centigrade. In this second model, the cool gas of low density — with a relatively small spread in random radial velocities — is supposed to fill rather uniformly the space between our sun and the more remote clouds of the denser, hotter gas. The cool gas produces the central dip in the 21-cm. scans near the galactic center. Heeschen gives evidence that on this model the hot regions may be associated with a spiral arm about 6,000 light-years from the sun. The average gas density in the cool region would be only 1/10 that in the hot regions.

At the Naval Research Laboratory, Hagen and his group have studied not only the radiation from neutral hydrogen atoms, but also that from *ionized* hydrogen emitted at wave lengths differing significantly from the 21-cm. line. What is known about the continuous "background" radiation with wave lengths from a few centimeters to 50 or so?

A little more than a year ago, P. A. G. Scheuer and Martin Ryle, of the Cavendish Laboratory in Cambridge,

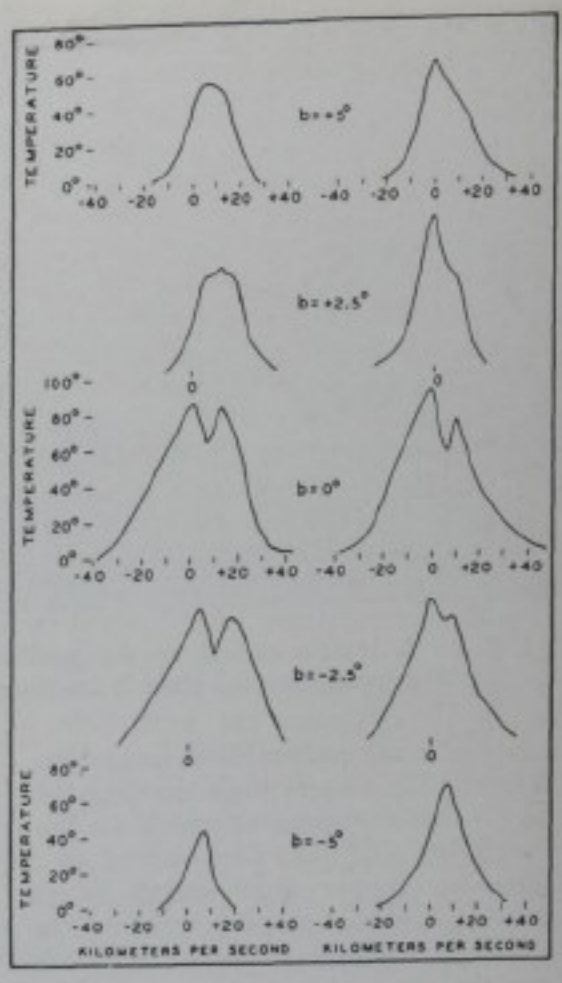

Fig. 5. Each of the 21-cm. profiles, plotted here from observations of the region of the galactic center, is the average of three to six individual scans. The radial-velocity scale is negative for approach and positive for recession; the vertical scale is brightness temperature. The profiles at the left are for galactic longitude 332°, and those at the right for 327°. The galactic latitude ranges from +5° to −5°.

England, found the first evidence that ionized hydrogen atoms in Milky Way gas clouds gave off appreciable radiation in the meter range. This was confirmed and extended last December, when F. T. Haddock, C. H. Mayer, and R. M. Sloanaker, of the Naval Research Laboratory, announced the discovery of 10 discrete sources of radio emission at a wave length of 9.4 centimeters. The fact that several sources were readily identified with the best-known optical emission nebulae (the Orion nebula was one of them) made it seem likely that the ionized hydrogen atoms recombining with free electrons were responsible for the observed radiation.

A few months later, Hagen, E. F. McClain, and N. Hepburn made a careful search for radiation from various directions in and outside the Milky Way,

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FACING PICTURE: In this photograph of the southern Milky Way near the Sagittarius-Scorpius boundary, a large dark nebula overlies the lower right part of the field. The picture is an enlargement from a photo taken in red light by Willem D. Victor with the Armagh-Dunsink-Harvard telescope of the Boyden station. It is near right ascension 17h 50m, declination −30°.

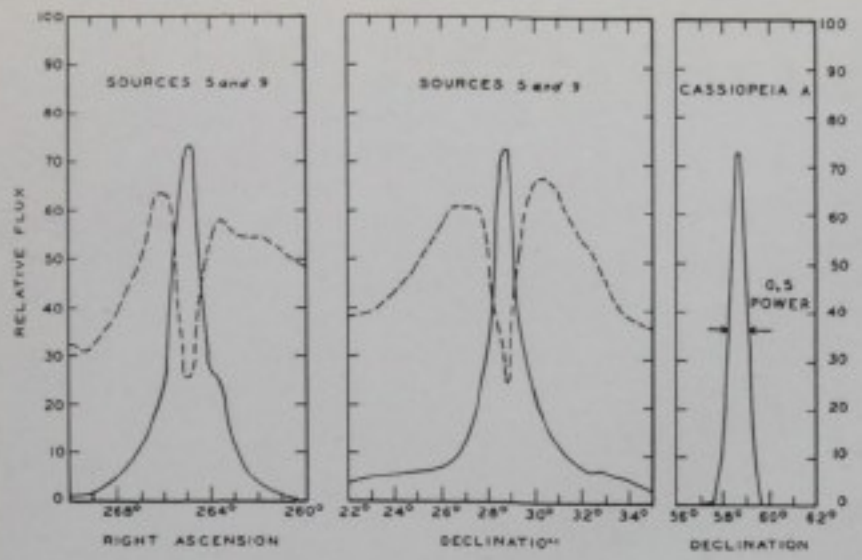


Fig. 6. Radio observations of Sources 5 and 9, near the galactic center, and of the radio star Cassiopeia A. The dashed curves show the intensity at a fixed frequency in the 21-cm. line; the solid curves refer to the intensity of the continuum outside the 21-cm. line. Data from the Naval Research Laboratory.

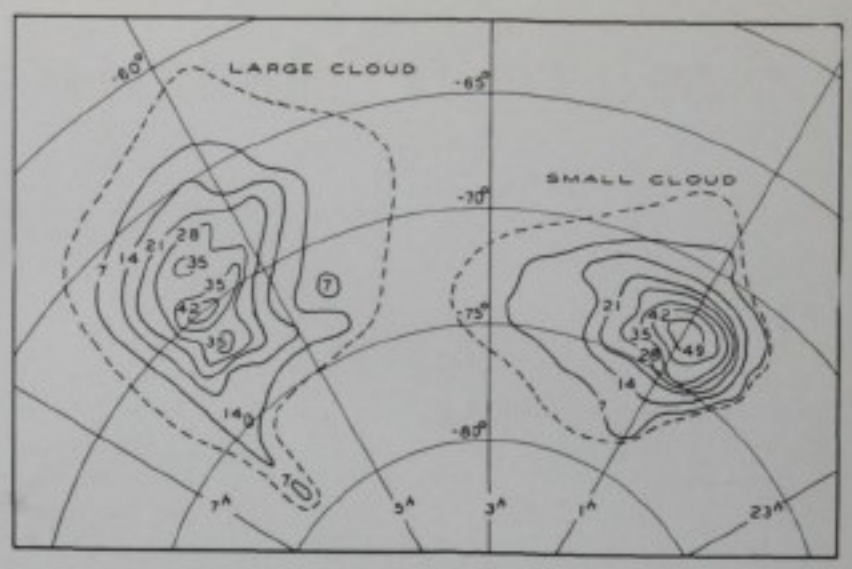


Fig. 7. This chart of the Magellanic Clouds was prepared from 21-cm. observations made in Australia by F. J. Kerr, J. V. Hindman, and B. J. Robinson. The curves are contours of equal hydrogen brightness; the dashed lines indicate the limits to which 21-cm. radiation was detected.

at wave lengths in the continuous spectrum near but well outside the 21-cm. line. This search with the 50-foot reflector of the Naval Research Laboratory — the largest precision radio mirror now in operation — proved exceedingly fruitful, and no less than 20 sources were located. Most of these are obviously associated with known optical objects rich in ionized hydrogen.

These are some of the sources now recognized as emitters in the continuous radio spectrum near 21 centimeters: 1, the Orion, Trifid, Omega, and North America nebulae, and seven other known regions of ionized hydrogen; 2, the three best known radio stars — in Cygnus, Cassiopeia, and Taurus (the Crab nebula) — and four other previously known discrete sources; 3, strong radiation from the direction of the center of the Milky Way system (Fig. 6).

The graphs of Fig. 6 present two very different phenomena. At the right, the solid line shows Cassiopeia A as a sharp peak without any "wings" at the base, whereas the two graphs for the direction of the galactic center have much greater width and broad wings. These curves confirm the earlier suggestion that here we are dealing with radiation from two overlapping sources, Nos. 5 and 9 on the list by Hagen and his group. The broad wings are then produced by the extended source, No. 9, and the strong sharp peak reaches us from the small but very intense source, No. 5, which may well be the center of our galaxy. A surprising result is that of the dashed curves, which refer to observations at a fixed frequency inside the 21-cm. line. The dips at the central position of source No. 5 are probably due to absorption effects by the neutral hydrogen itself.

Very recently McClain has studied source No. 5, using a receiver with very high resolution in wave length. His scans exhibit apparently as many as four different peaks. Whatever the final outcome of these researches may be, the workers at the Naval Research Laboratory are evidently digging into the very heart of our Milky Way, which to date no one has succeeded in directly observing by optical means!

We turn, in conclusion, to Australian radio astronomers, and particularly to their epoch-making results regarding the two Magellanic Clouds. The Large and Small Clouds are companion galaxies of our own Milky Way system. It had been known for many years that ionized hydrogen is present in both clouds, especially in the larger, which contains some of the most beautiful emission nebulae anywhere in the sky. The most important result obtained by the Australian radio astronomers is shown graphically in Fig. 7. The Large Cloud has its greatest 21-cm. radiation intensity near right ascension $5^h\ 40^m$, declination $-70°$; the Small Cloud, near 1^h, $-73°$.

Two aspects of Fig. 7 are especially worthy of comment. First, the extent of the two clouds is considerably greater in radio radiation of neutral hydrogen than optically. As a matter of fact, the dashed-line boundaries of the two clouds are almost in contact, suggesting that a mutual thin hydrogen envelope may exist. Second, the Small Cloud is not really very much smaller than the Large Cloud, an observation that came somewhat as a surprise.

From photographic evidence, many of us had expected that the Small Cloud would have considerably less hydrogen than the Large Cloud, but this seems hardly to be the case. There is no doubt that the high concentration of hydrogen in the Small Cloud will figure prominently in future work on stellar evolution in the two clouds. The concept held earlier by some astronomers, that the Small Cloud is an aged galaxy that has already used up most of its hydrogen in evolutionary processes, is now shown to be wrong.

The Australian astronomers have estimated the respective total amounts of hydrogen gas in the two clouds as 600 million and 400 million solar masses — about 20 per cent of the total estimated mass of each cloud: gas, dust, and stars combined. The Small Cloud has probably a very much lower dust content than the large one, suggesting that it has a considerably smaller dust-to-gas ratio than the latter.

From 21-cm. scans of the Magellanic Clouds, much useful information may be obtained regarding the distribution of velocities in them. The Australians have only just begun work on this, but their first analysis already shows that each cloud is rotating on its axis and, further, that the relative velocity of the two clouds is about 50 kilometers per second.

The foregoing summary of the current status of 21-cm. research is of necessity incomplete. We have not touched on several aspects, such as the very recent ingenious suggestion by two radio astronomers, at the Jodrell Bank station near Manchester, that approximate distances for discrete radio sources may in the future be determined from the absorption effects produced by galactic neutral hydrogen. But the present survey should suffice to show that 21-cm. research is an active field rich in promise.

NOTICE to all Readers

Your copy of *Sky and Telescope* for this month has probably been late in reaching you. Repeated power failures due to the two New England hurricanes, Carol and Edna, seriously disrupted our production schedule. We are sorry for the unavoidable delay. —ED.

Amateur Astronomers

A New Planetarium in the Ozarks

IN THE HEART of the Missouri Ozarks, the E. D. Tarbell Planetarium, Observatory and Museum was dedicated June 6, 1954. It is eight miles from Waynesville and just a few minutes from highway 66.

The planetarium building is on a knoll some 500 yards from the entrance to Inca Cave, one of the largest natural caves in the Middle West. The planetarium will be open to the general public as a tourist attraction, as well as to schools, military installations in the area, and other groups as a teaching aid.

The sky chamber is entered through a light-proof vestibule adjoining an entrance lobby facing southeast in a corner of the building. The octagonal chamber seats 100 persons; its horizon is painted in silhouette to represent the Ozark timberline and surrounding hills. Adjacent is a museum room where indirectly lighted photographs are displayed on three walls. At the center of the east wall are large reproductions of Lick Observatory photographs of the moon at first and last quarter; the other photographs are feature pictures from *Sky and Telescope*, which will eventually be replaced with illuminated transparencies of the same objects.

Other rooms in the building include those for shop and storage, two rest rooms, a corner office, and a small heating and air-conditioning room.

In the south wall of the sky chamber is an exit door that will lead to an observatory 200 inches in diameter at floor level. It will house a Newtonian-Cassegrainian 12-inch reflector that Mr. Tarbell built. He will continue to use it for observations of variable stars except when it is required for public observing.

The planetarium projector is a Spitz Model A, with console and several special attachments. Other equipment includes a sound system for music and sound effects, and a projector for lantern slides. It was necessary to drill a well through 367 feet of hard rock to provide sufficient water to operate the building.

Actual construction of the building was begun in May, 1953, by H. B. Terry, a local contractor, but Mr. Tarbell planned, formed, and installed the 24-foot dome room of the planetarium chamber. The dome framework consists of 32 wood ribs fashioned by hand from short pieces of 2 x 4 stock and spliced together and bolted. When finished, each rib was equal in section to a 2 x 6 curved beam. A wooden ring 24 feet inside diameter, made in a similar manner, was bolted on metal angle supports set into the dome room walls, its height six feet 4½ inches above the finished floor; the horizon is at this point.

The crown of the dome is a "wheel" 42 inches in diameter and 5½ inches thick. It provides a recess into which a 12-inch loud-speaker is fitted. A heavy wire was drawn around the dome support midsection and tightened with turnbuckles to give rigidity to the entire assembly.

Tongue-and-groove wood sheeting was nailed onto the ribs, filling each of the 32 spaces separately. Over the wood are asphalt roof paper and finally 24-gauge aluminum sheeting, the sections cut by hand, with a standing overlap seam that is caulked to provide a watertight covering.

Blanket rock wool insulation was nailed between the dome ribs from the inside, the speaker and wiring laid, and all was covered with wood sheeting to which sheet aluminum is fastened. Special aluminum joint cement was used to give the inside of the dome a very smooth spherical surface. Four coats of flat white paint added the finish to the artificial sky, the painting being done by Mrs. Tarbell and Miss Margaret Tarbell.

The dedication and opening to the public was conducted by a committee of members from the amateur astronomical societies of Fayette, St. Louis, and Kansas City, under the chairmanship of the author, who also acted as program moderator for the meeting. Seventy-five amateur and professional astronomers attended, and were given a tour of Inca Cave.

Russell C. Maag
Sedalia, Mo.

The Tarbell Planetarium and Museum, near Waynesville, Mo.

THIS MONTH'S MEETINGS

Brooklyn, N. Y.: Brooklyn Institute of Arts and Sciences, 8:15 p.m., Academy of Music. Oct. 29, Charles A. Federer, Jr., Harvard College Observatory, "The Solar System Rejuvenated."

Dallas, Tex.: Texas Astronomical Society, 8 p.m., Dallas Power and Light Co. auditorium. Oct. 25, Jack Kucera, "Galaxies."

Geneva, Ill.: Fox Valley Astronomical Society. Oct. 16, annual banquet, Dr. G. C. McVittie, University of Illinois, "Report from the 200-inch Telescope."

Minneapolis, Minn.: Junior Astronomy Club, 4:15 p.m., Public Library. Oct. 13, Wensell S. Frantzich, Northwest Airlines, "Sweeping the Heavens." Oct. 27, Howard H. Gould, Minneapolis Astronomy Club, JAC solar eclipse films.

New York, N. Y.: Amateur Astronomers Association, 8 p.m., American Museum of Natural History. Oct. 13, G. Edward Pendray, American Rocket Society, "Space Revisited: 25 Years of Rocket Research."

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Department auditorium. Oct. 2, staff member, Applied Physics Laboratory, Johns Hopkins University, "Guided Missiles."

CLEVELAND STAR PARTIES' 25TH ANNIVERSARY

This summer marked the 25th year that star parties have been scheduled in the Cleveland parks, sponsored by the Cleveland **Press** and under the direction of its science editor, David Dietz. Telescopes have been supplied through the co-operation of members of the Cleveland Astronomical Society. At some parties, nearly 25 telescopes have been in use, and more than 5,000 visitors have turned out for a single night's observing.

COURSE SCHEDULE OF THE AMERICAN MUSEUM-HAYDEN PLANETARIUM

A SERIES of courses in popular astronomy, navigation, meteorology, and telescope making, designed to meet the needs of the layman, boating enthusiasts, scout leaders, naturalists, and teachers, has been scheduled for this fall at the American Museum-Hayden Planetarium, in New York City. The planetarium's Zeiss projector will be used whenever possible to illustrate the subject matter.

There are four astronomy courses: "Astronomy Round Table," by Henry M.

Neely, Tuesdays at 7:15 p.m., 15 sessions; "Star Identification," by Catharine E. Barry, Wednesdays at 7:15 p.m., 10 sessions; "Astronomy for the Family," by Miss Barry, Saturdays at 9:45 a.m., 10 sessions (designed especially for young people); and "Descriptive Astronomy for Teachers and Laymen," by Miss Barry, Wednesdays at 5:00 p.m., 30 sessions (alertness credit for New York City teachers).

A course of introduction to celestial navigation will be conducted on Thursday evenings at 7:15 p.m., by Joseph M. Chamberlain and Thomas D. Nicholson. This will be followed in the spring of 1955 with an advanced course in the same subject.

"Why the Weather" is the title of the meteorology course conducted by Frank H. Forrester on Monday evenings at 7:15 p.m.

As in the past, telescope mirror making classes will meet in the basement of the Hayden Planetarium, where instruction will be provided by members of the Optical Division of the Amateur Astronomers Association. This is the 22nd year for this course, which meets in two separate groups, one on Tuesday and one on Thursday evenings.

Interested persons may obtain full details of these courses, including fees and conditions of entry, by writing to the American Museum-Hayden Planetarium, 81st St. and Central Park West, New York 24, N. Y., or telephoning TRafalgar 3-1300.

WHITTIER ASTROPHYSICS SOCIETY

An amateur astronomy group started in Whittier, Calif., at the beginning of this year, and now holds evening meetings on the first and third Sunday of each month. The members built two 6-inch and two 8-inch telescopes, and expected to complete several more by the end of the summer with the aid of a new 15-inch grinding machine.

The society did meteor observing in April and May, and planned an extensive meteor program for the Pons-Winnecke, Delta Aquarid, and Perseid showers. Further information about the group may be obtained from G. A. McCue, 7855 S. Euclid Ave., Whittier, Calif.

NEW YORK SOCIETY'S PROGRAM

In its leaflet, Enjoy the Stars, the Amateur Astronomers Association announces its schedule of lectures, classes, and other activities for 1954-55, its 28th season. Classes this year include elementary astronomy, taught by W. Wallace Benjamin; astronomy with a camera, Robert G. Knittel, instructor; a seminar on recent advances in astronomy, with Mary W. Schiffmann as chairman; and a course in constellation study, by Patrick Rizzo. Telescope mirror-making classes will again be presented in the Optical Division workshop in the Hayden Planetarium.

AAA headquarters are in the Roosevelt memorial building of the American Museum of Natural History. Lecture meetings are held on the first Wednesday of each month, except for the October 13th meeting, when the fourth Clyde Fisher memorial lecture will be given.

Further information may be had from the assistant secretary, Miss Jane S. Davis, Amateur Astronomers Association, American Museum of Natural History, New York 24, N. Y.

ASTRONOMICAL SCRAPBOOK

Astronomical Murders and Misadventures

THE WRITERS of mystery stories, in their anxious search for novel plots and fresh atmosphere, have on a few occasions hit upon astronomical settings for their crimes. But such efforts have as a rule little attraction to the reader who is himself an astronomer, because of blunders in attempting to supply astronomical color. It is tantalizing that a few years ago one of the most versatile of living woman astronomers began writing a novel with the title, "Murder Under the Dome," still evidently unfinished.

Even so, real life supplies quite a number of instances of astronomers who have died violent deaths, or who have succumbed to unusual accidents. Fortunately, the one known attempt at a mass murder of astronomers failed. This was at the Greenwich Observatory on February 15, 1894. A nearby explosion was heard which one staff member, following a praiseworthy astronomical reflex, timed at 4:15:25 p.m. exactly. A little later, searchers found lying on a nearby wooded path a terribly mutilated man, who died soon after. The police established that this was the anarchist Martial Bourdin, who on his way to blow up the Greenwich Observatory was the victim of a premature explosion of his own bomb.

The name of David Fabricius (1564-1617) is remembered today, for he found that Mira Ceti is a variable star, a discovery from which a major branch of present-day astronomy has sprung. We might imagine that as the pastor of a sleepy country village in northern Germany his life would have been peaceful and secure. Instead, violence took a rustic form. A goose belonging to Fabricius was stolen, and the next Sunday from the pulpit he hinted at the identity of the peasant who took it. The alarmed thief killed the astronomer-clergyman to prevent further disclosures.

While he has little claim to fame as an astronomer, the story of Johann Hennings is a curious one. Born in 1708, he became professor of physics at the University of Kiel, where in 1738 he published a book on the possibility of life on other planets. After his retirement in 1763, he became devoted to alchemy. He was found murdered in his bed, apparently by the soldier whom he used as an assistant in his gold-making experiments.

If you have ever had much need of logarithm tables, you probably know of those by Baron von Vega, first published in 1794, later revised by Bremiker, and after many editions still widely used today. Vega was an Austrian artillery officer who devoted himself to astronomy and mathematics. His death in September, 1802, was long a celebrated mystery, after his body was found in the Danube River, not far from Vienna. Not until 30 years later was the identity of his murderer, a miller, finally determined.

A second connection between table-making and crime is afforded by the case of Don José Mendoza y Rios (1763?-1816), a captain in the Spanish navy, who did much for nautical astronomy, and compiled many navigational tables. The Spanish admiralty sent him in 1789 to England with 1,300 000 reals to buy scientific books, but he settled down comfortably in London, never to return, despite repeated orders. His scientific and social standing was good enough to win him membership in the Royal Society. Courts-martial seem to have moved slowly in those days, for it was not until 1800 that the Spanish navy finally dismissed him and cut off his pay. A contemporary account says that he hung himself from exasperation at finding an error among the millions of numbers in his tables — a punctiliousness which seems improbable in view of his earlier exploit.

Excusable homicide and murder can be hard to distinguish. The reader may form his own judgment in the case of Pierre Gassendi (1592-1650), astronomer to the king of France and opponent of astrology, after whom the well-known lunar crater was named. He died the victim of his physicians, who bled him with leeches 13 times in rapid succession.

Even where there is no question at all of crime, astronomers' mishaps can take curious forms. Jacques Vidal (1747-1819), director of the Toulouse Observatory, succumbed to a stroke in the very act of measuring the position of a comet in Pegasus. The inventor of the Gregorian reflector, James Gregory (1638-1675), was at the telescope observing Jupiter's satellites when he suddenly became blind; he died a few days later.

The fates of several astronomers are puzzling. No one knows whether the French astronomer d'Agelet perished in a shipwreck or was eaten by cannibals. And finally, what are we to make of the cryptic remark of a biographer that Franciscus Junctinus died at Lyons in 1590, "killed by his own books"?

J. A.

Interplanetary dust: the zodiacal light as drawn by E. Leopold Trouvelot about 80 years ago. In northern latitudes in the fall, it is seen best before dawn, sometimes appearing as bright as the Milky Way.

COSMIC DUST

By Otto Struve, *Leuschner Observatory*
University of California

About 150 astronomers attended the sixth international astrophysical symposium on July 15-17, 1954, organized by Professor P. Swings and the Institut d'Astrophysique of Liége University, Belgium. "Solid Particles in Astronomical Objects" was the theme of the 63 papers on the program; two thirds of these were by American, British, and German astronomers; the others came from Belgium, Czechoslovakia, France, Holland, Japan, Poland, Sweden, and the U.S.S.R.

The first of the five sections into which the program was divided was entitled "Dust in the Solar System." It started with a summary by M. Minnaert, who drew heavily upon the theoretical work of H. C. van de Hulst in Holland and H. Elsaesser in Germany, and upon the recent observations by the German astronomers, A. Behr and H. Siedentopf. Dr. Minnaert discussed first the connection between the zodiacal light and the F-corona of the sun, phenomena described in the March issue of *Sky and Telescope*. Both are caused by the scattering of sunlight: by small solid particles, and by free electrons produced by the ionization of gaseous atoms expelled by the sun or that result from the evaporation of solid grains when they come closer to the sun's surface than four solar radii.

Although the zodiacal light appears to the eye as a narrow cone, measurements of its intensity show that it is really quite broad. Its polarization was recently found by Behr and Siedentopf to reach 20 or 30 per cent, especially at great elongations from the sun. Since solid particles cannot account for more than four per cent of the polarization, this result indicates that electrons are abundant at great distances from the sun. They had already been assumed to be abundant near the sun's photosphere, their motions of hundreds of kilometers per second causing the washed-out or dish-shaped appearance of the lines of the spectrum of sunlight as reflected or scattered by the F-corona.

The zodiacal light appears much brighter near the sun than at the apex of its cone at great solar distances. It had hitherto been assumed that the brightest parts had the greatest density of dust particles. But in 1947 van de Hulst showed that this earlier conclusion was erroneous because it neglected the effect of diffraction, which for moderately large particles concentrates much more light in the forward direction. Therefore, relatively few particles seen in front of the sun's edge would scatter as much light as a greater number of particles devoid of diffraction.

It is therefore understandable that the new results of Behr, Siedentopf, and Elsaesser indicate a decrease in the density of zodiacal light particles at solar distances less than 0.6 astronomical unit. In general, the dust seems to form a flat ringlike layer in the plane of the ecliptic, with a "hole" around the sun. The density of this layer decreases by a factor of 2.72 for every quarter of an astronomical unit above and below the ecliptic.

The distribution of the particle sizes was derived by van de Hulst in 1947 and by Elsaesser in 1954. Most particles range between about one and 0.001 millimeter, but their number per cubic centimeter at a distance of one astronomical unit from the sun exceeds by 10,000 the number expected from the counts of meteors. The latter are, however, mostly high-velocity particles, moving around the sun in highly eccentric, cometlike orbits. Van de Hulst concludes that the solar system contains a vast accumulation of small grains which move around the sun in approximately circular orbits, in accordance with Kepler's laws. These grains would rarely collide with the earth — it is only an exceptional cometlike interloper that we observe as the flash of a shooting star.

The electrons form a huge cloud around the sun, their surfaces of equal density comprising ellipsoids of revolu-

tion with a ratio of two to one for their axes in the ecliptic and at right angles to it.

Minnaert discussed one very strange result, derived by van de Hulst, concerning the albedo or reflecting power of the particles composing the zodiacal light. At large angles of elongation, diffraction is unimportant and ordinary Lambert-type scattering accounts for most of the surface brightness. The latter is, in turn, proportional to the albedo. Van de Hulst had derived the density distribution of the particles from the diffraction effects at small elongations from the sun, and therefore was able to compute their albedo on the basis of Lambert-type scattering at large distances. His result was 0.005 — almost black! Direct measurements on meteorites, which do look almost black, give about 0.1.

But Elsaesser found it is possible to reconcile the observations with the assumption that the particles are white, albedo equal to 1.0. Hence, we are still uncertain as to the reflectivity of the grains. Minnaert, following F. L. Whipple, is inclined to believe that at great solar distances these grains consist mostly of ices, with metallic impurities. Presumably, such particles would be almost white.

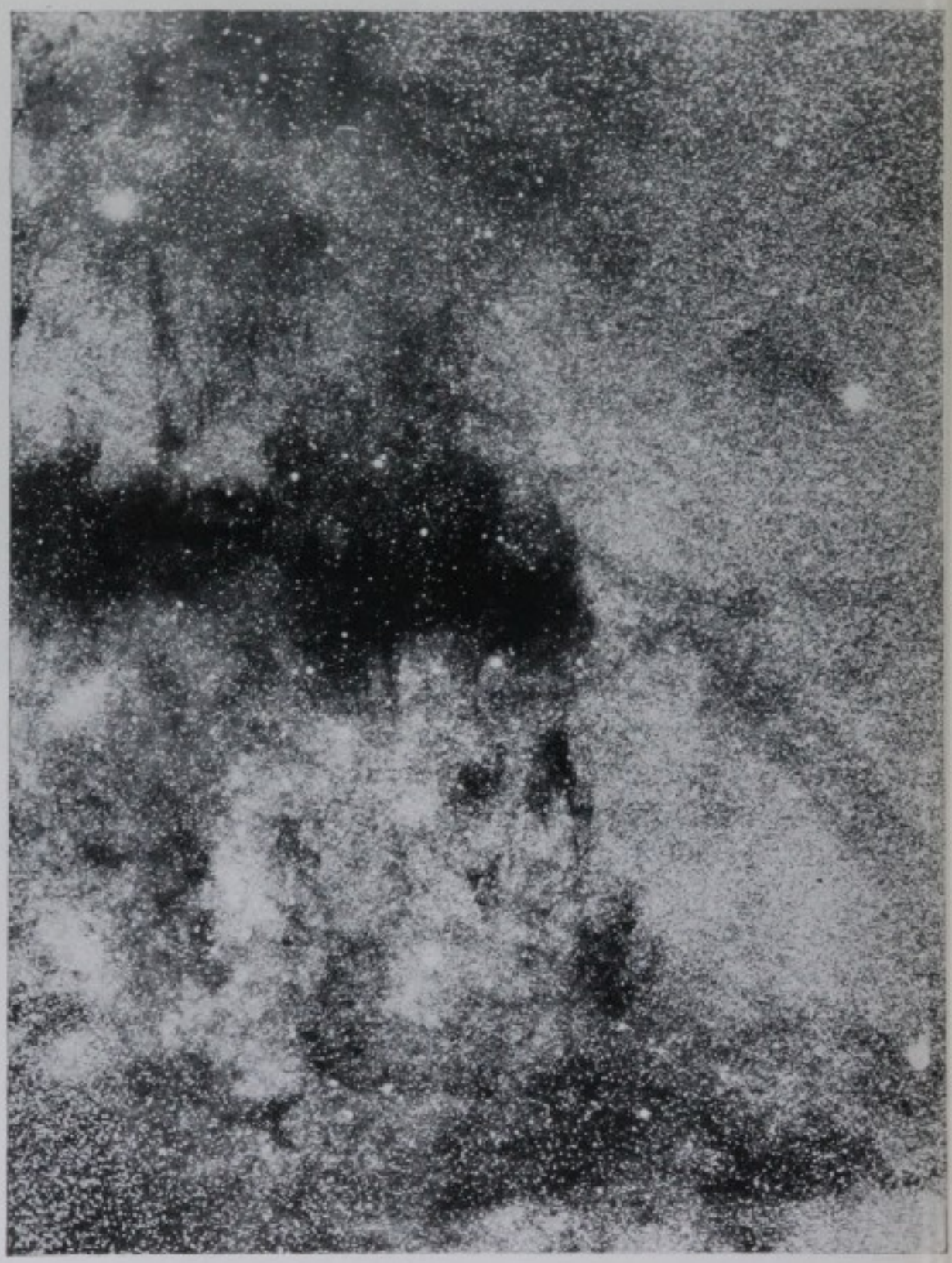
Where do they come from? All speakers, especially Dr. Whipple, agreed that they cannot exist for a very long time without either being drawn into the sun and evaporated or being pushed out of the solar system by radiation pressure. As Dr. Whipple has suggested, disintegrating comets may continually replenish the supply of small particles (see page 373, September issue).

The second section of the symposium, presided over by me, was devoted to phenomena in stars that could be explained in terms of clouds of solid particles. I discussed the theory of veiling, as developed by P. W. Merrill, J. O'Keefe, and G. H. Herbig, and continued with my own recent results on the "iron nebula" around the *B*-type companion of Antares. The problem of Antares was also discussed in a paper by Dr. O'Keefe, who suggested that the variations of the supergiant's diameter might be explained in terms of highly efficient reflecting clouds of quartz particles, these resulting from the condensation of silicon dioxide gases into clouds of solid grains.

Laboratory spectra, studied for their relations to celestial phenomena involving graphitic particles, were summarized in the third section by G. Herzberg, of Canada. He discussed the formation of interstellar molecules by radiative two-body recombinations and by exchange reactions of the type $AB + C \rightarrow A + BC$. The latter might lead to the formation of molecules like N_2, H_2, and NH, which are not likely to be formed by two-body recombinations. The unidentified, diffuse interstellar lines (at wave length 4430.6, and others) may be due to predissociated absorption bands of triatomic free radicals similar to those of HCO (hydrogen-carbon-oxygen). Dr. B. Rosen discussed his own work and that of L. Brewer and J. Phillips on the continuous absorption of C_3 molecules in laboratory sources. A. McKellar and H. Richardson reported that in all probability these same molecules cause the heavy blue and violet absorption in cool carbon stars.

The largest section was devoted to "Smoke in Interstellar Space and in Nebulae." Van de Hulst reviewed the evidence on the chemical composition of the grains, their temperatures, distribution of sizes and shapes, and their densities in different regions of the Milky Way.

The observed degree of obscuration amounts, on the average, to two magnitudes per kiloparsec, and could be achieved only by negative hydrogen ions, or by small ice grains about one micron in diameter, or by iron particles about 1/10 as large. All other types of particles would require such heavy concentrations in space as to make the total mass of the interstellar medium unreasonably large. Negative hydrogen ions do not form often enough in hydrogen gas clouds to play an important role.



This long-exposure photograph of the Milky Way in Ophiuchus and Scorpius, by E. E. Barnard, shows extensive dust clouds silhouetted against the stellar background. The bright star near the upper left corner is Theta Ophiuchi; at the upper right is the globular cluster M19; at the lower right margin is M62.

This leaves only ice crystals and iron particles. Both could produce the observed relation of absorption and wave length. But van de Hulst prefers the ice crystals because they have larger albedos and they scatter light in a predominantly forward direction. From the prior work of L. G. Henyey and J. L. Greenstein, it appears certain that the obscuring clouds in the Milky Way do in fact possess these properties.

The existence of interstellar polarization shows that the particles are not spherical in shape, but rather elongated needles or ellipsoids that show a predominantly parallel orientation. There are three competing theories to explain this orientation. Two, by L. Davis and Greenstein on the one hand, and by L. Spitzer, Jr., and J. Tukey on the other, attribute it to interstellar magnetic fields. But the former make use of a phenomenon known as paramagnetic relaxation, which operates upon ice needles rotating haphazardly in all directions as a result of mutual collisions. These rotations are modified by magnetic forces in such a manner as to produce a predominant orientation along the lines of magnetic force. The Spitzer-Tukey mechanism operates upon iron needles. Since most astronomers believe that the interstellar particles are dielectric rather than metallic in composition, the Davis-Greenstein mechanism is usually regarded as the more probable of the two. It has also the advantage of requiring a smaller interstellar magnetic field — of the order of 10^{-5} gauss — which fits well with the theory of interstellar magnetism developed during the past year by E. Fermi and S. Chandrasekhar.

The third theory, by T. Gold, attributes the orientation of the particles to what might be called "interstellar winds." If the motions of the interstellar gas tend to be directed predominantly at right angles to the plane of the Milky Way, then the elongated particles would indeed orient themselves in a preferential manner and would produce the observed kind of polarization in a transmitted beam of starlight.

At the symposium, Mr. Gold read a paper describing his theory and extending it to the case of relatively mild winds. His previous theory was concerned with more violent gas motions, of a supersonic character. Dr. Davis, who was not present, had sent a paper in support of the Davis-Greenstein theory. There ensued a lively discussion in which Mr. Gold defended his views, but the majority of the astronomers present seemed to be more inclined to accept the Davis-Greenstein mechanism.

Nevertheless, one can agree with Gold that the winds, if they exist, must influence the distribution of the major axes of the particles in space, and it is therefore important to explore how far we can go without invoking the action of magnetic fields. Perhaps both mechanisms play a role. After all, van de Hulst showed that even with a perfect alignment of all particles it is not easy to account simultaneously for the observed amounts of obscuration and polarization. Neither theory, by itself, predicts such a perfect alignment. If several forces were operating to orient the particles in the same way, the alignment would be more nearly perfect, and the difficulty would be less severe.

The southern Milky Way from Centaurus to Carina is shown on this Harvard Observatory photograph, a 90-minute exposure with a 3-inch camera. Crux, the Southern Cross, is near the center, and at its left is the southern Coalsack, perhaps the most famous dark nebula in the heavens. The field is about 35 degrees wide.

A very important result of the observations, stressed especially in a paper contributed by Mlle. Lucienne Divan, of Paris, is the fact that the curve that relates the amount of interstellar absorption and the wave length is the same in all regions of the Milky Way thus far investigated — even in the Orion nebula, where previous investigators had found a marked anomaly. Oort and van de Hulst have suggested that interstellar grains grow quite rapidly around nuclei of condensation, which may, to begin with, be nothing more substantial than polyatomic molecules. They find that in 10^8 years an average particle reaches a diameter of about one micron. This is what the observations indicate for the particles in all dark nebulosities. Since the Milky Way galaxy is certainly much older than 10^8 years, we arrive at one of several conclusions:

1. There must be a mechanism whereby the particles are prevented from growing beyond one micron. This may be due to collisions of dark clouds and the consequent evaporation of colliding grains.

2. It is surprising that all clouds show the same average size of particle. If some clouds are very young while others are old, the observed absorption curves would not all give the same relation with wave length. The fact that the curves are the same suggests that in the vicinity of the sun — in our own spiral arm of the galaxy — all clouds are old enough to have reached equilibrium conditions.

3. The mechanism of particle production may not be at all the one considered by Oort and van de Hulst. In fact, Dr. Oort in his introductory paper recommended further study of the mechanism of pulverization of meteoric particles, recently advanced by H. Zirin at Harvard, which has many advocates for zodiacal light formation but had seemed rather improbable for interstellar dust.

Dr. Oort stressed the great predominance of gas in all interstellar clouds. According to the Leiden radio observations, and also according to the Harvard work by B. J. Bok and his associates, described on page 408 of this issue, the average density of the gas is at least 100 times that of the solid particles. The gas, and not the dust, is the primary factor connected with the formation of spiral arms. A galaxy deprived of its gaseous constituent, perhaps as the result of a collision with another galaxy,

can become greatly flattened, but it is incapable of forming spiral arms or knots.

Can solid grains condense in all gaseous regions of the Milky Way? Oort's answer is "no." He said, "It must be expected that at densities less than 1/10 that near the sun practically no solid particles can exist. We may conclude that wherever absorption effects are observed the average gas density must exceed 0.1 hydrogen atom per cubic centimeter."

The final section of the symposium was introduced by B. Stroemgren, of Yerkes Observatory. He reviewed, in particular, our knowledge of the abundances of heavy atoms (heavier than hydrogen and helium) in different classes of stars. The importance of this information for the study of cosmic dust is evident when we attempt to reconcile theories of star formation and evolution with the constitutions of the stars. Dr. Stroemgren suggested that the best estimates of the proportion of the heavy elements in different groups of stars are:

3% for young stars of Population I (spectral types *O*, *B*, and *A*)

2% for average-aged stars (type *F*)

1% for old stars of Population I (Sun)

0.1% for very old stars of Population II (globular clusters and the like)

10% or more for subgiants of Algol-type binaries

The first four groups indicate a decrease of heavy elements with increasing age. This could mean that at a very early stage of the universe there was more hydrogen available for star formation than there is at the present time. But the Algol-type subgiant companions do not fit into this picture. Either they are really poor in hydrogen because of some unrelated cosmogonical cause or they are evolving with a rapid loss of mass, whereas single stars evolve while essentially preserving their original masses. This possibility for the Algol-type subgiants has recently been explored by John Crawford at Berkeley, and it was strongly supported by Z. Kopal, of Manchester, in the discussion of Dr. Stroemgren's paper.

The Yerkes astronomer was inclined to attribute only a minor importance to the Spitzer-Whipple process, whereby the formation of stars out of dark nebulosities, depending as it does upon radiation pressure, affects the solid grains to a much greater extent than the gaseous atoms and molecules. Once formed, such stars' heavy-element constitutions should remain generally unchanged, as the percentages above indicate, because the theory of nuclear conversion of hydrogen into helium does not noticeably affect the abundances of the heavy elements, even though some of them may play a part in the star's energy production.

Instead, Dr. Stroemgren briefly sketched some new ideas of Oort, Spitzer, and others, who start with the fact that we often find one or several *O*-type stars embedded in a dark nebula. Without answering the question of where the *O* stars originated, they ask what will happen next. Apparently, the radiation pressure of the hot *O* star produces a radial outward push on the surrounding dark material. The nebula expands and the outward-moving parts become highly compressed. Filaments are formed in the compressed layer, which continues to expand, and may provide conditions of density and temperature that are suitable for star formation by gravitational contraction. The result is an expanding star cluster or association of the type predicted by V. A. Ambarzumian and actually discovered by A. Blaauw.

A somewhat similar theory was presented by E. Opik, Armagh Observatory, who starts with a supernova instead of an *O* star. But the problem immediately arises of whether or not the supernovae are sufficiently frequent to form the billions of stars of each galaxy.

Planetarium Notes

(Most planetariums give group and special showings by appointment.)

BALTIMORE: *Davis Planetarium.* Maryland Academy of Sciences, Enoch Pratt Library Building, 400 Cathedral St., Baltimore 1, Md., Mulberry 2370.

SCHEDULE: 3:45 p.m. Monday and Friday (Sept.-June); Thursday, 7:15, 7:45, 9:00 p.m. Admission free. Spitz projector. Director, Paul S. Watson.

BUFFALO: *Buffalo Museum of Science Planetarium.* Humboldt Parkway, Buffalo, N. Y., GR-4100.

SCHEDULE: Sunday, 2:00 to 5:30 p.m. Admission free. Spitz projector.

CHAPEL HILL: *Morehead Planetarium.* University of North Carolina, Chapel Hill, N. C.

SCHEDULE: Daily at 8:30 p.m.; also 11 a.m. and 3 p.m. Saturdays, 3 and 4 p.m. Sundays. Zeiss projector. Manager, A. F. Jenzano.

CHARLESTON, W. VA.: *Hillis Townsend Planetarium.* Public Library Building, Charleston, W. Va.

SCHEDULE: Saturday, 11:15 a.m. Special showings on request. Admission free. Spitz projector. Director, Louise L. Morlang.

CHEROKEE, IA.: *Sanford Museum Planetarium.* Sanford Museum, 117 E. Willow St., Cherokee, Ia.

SCHEDULE: Monday, 8 p.m. (except August). Admission free. Spitz projector. Director, W. D. Frankforter.

CHICAGO: *Adler Planetarium.* 900 E. Achsah Bond Drive, Chicago 5, Ill., Wabash 2-1428.

SCHEDULE: Mondays through Saturdays, 11 a.m. and 3 p.m.; Tuesdays and Fridays, 8 p.m.; Sundays, 2:00 and 3:30 p.m. Zeiss projector. Director, Wagner Schlesinger.

KANSAS CITY: *Kansas City Museum Planetarium.* 3218 Gladstone Blvd., Kansas City 23, Mo., Humboldt 8000.

SCHEDULE: Saturday, 3:00 p.m.; 2nd and 3rd Sundays, 3:00 and 4:30 p.m. Spitz projector. Director, Kenneth W. Prescott.

LOS ANGELES: *Griffith Observatory and Planetarium.* Griffith Park, P. O. Box 27787, Los Feliz Station, Los Angeles 27, Calif., Normandy 4-1191.

SCHEDULE: Wednesday, Thursday, and Friday at 8:30 p.m.; Saturday and Sunday at 3 and 8:30 p.m.; extra show on Sunday at 4:15 p.m. Zeiss projector. Director, Dinsmore Alter.

NASHVILLE: *Sudekum Planetarium.* Children's Museum, 724 2nd Ave. S., Nashville 10, Tenn., 42-1858.

SCHEDULE: Sunday, 2:45, 3:30, 4:15. Spitz projector. Associate curator of education, Burton Ingram.

NEWARK: *Newark Museum Planetarium.* 49 Washington St., Newark 1, N. J., Mitchell 2-0011.

SCHEDULE: Saturday and Sunday, 2:30 and 3:30 p.m. Group showings on request on weekdays and Wednesday and Thursday evenings. Admission free. Spitz projector. In charge, Ray Stein.

NEW YORK CITY: *American Museum—Hayden Planetarium.* 81st St. and Central Park West, New York 24, N. Y., Trafalgar 3-1300.

SCHEDULE: Mondays through Fridays, 2, 3:30, and 8:30 p.m.; Saturdays, 11 a.m., 1, 2, 3, 4, 5, and 8:30 p.m.; Sundays and holidays, 1, 2, 3, 4, 5, and 8:30 p.m.; Mondays, Wednesdays, Thursdays and Fridays, 11 a.m., for school groups. Zeiss projector. General manager, J. M. Chamberlain.

PHILADELPHIA: *Fels Planetarium.* Franklin Institute, 20th St. at Benjamin Franklin Parkway, Philadelphia 3, Pa., Locust 4-3600.

SCHEDULE: Tuesdays through Sundays, 3 p.m.; Saturdays, 11 a.m.; Saturdays, Sundays, and holidays, 2 p.m.; Wednesdays, Fridays, and Saturdays, 8:30 p.m. Zeiss projector. Director, I. M. Levitt.

PITTSBURGH: *Buhl Planetarium and Institute of Popular Science.* Federal and West Ohio Sts., Pittsburgh 12, Pa., Fairfax 1-4300.

SCHEDULE: Mondays through Saturdays, 2:15 and 8:30 p.m.; Sundays and holidays, 2:15, 4:15 and 8:30 p.m. Zeiss projector. Director, Arthur L. Draper.

PORTLAND, ORE.: *Oregon Museum of Science and Industry Planetarium.* 908 N.E. Hassalo St., Portland 12, Ore., East 3807.

SCHEDULE: Saturday and Sunday, 3:00 p.m. Spitz projector. Director, Stanley H. Shirk.

PROVIDENCE: *Roger Williams Planetarium.* Roger Williams Park Museum, Providence 5, R. I., Williams 1-5640.

SCHEDULE: Saturdays, Sundays, and holidays, 3 and 4 p.m. Admission free. Spitz projector. Director, Maribelle Cormack.

SAN FRANCISCO: *Morrison Planetarium.* California Academy of Sciences, Golden Gate Park, San Francisco 18, Calif., Bayview 1-5100.

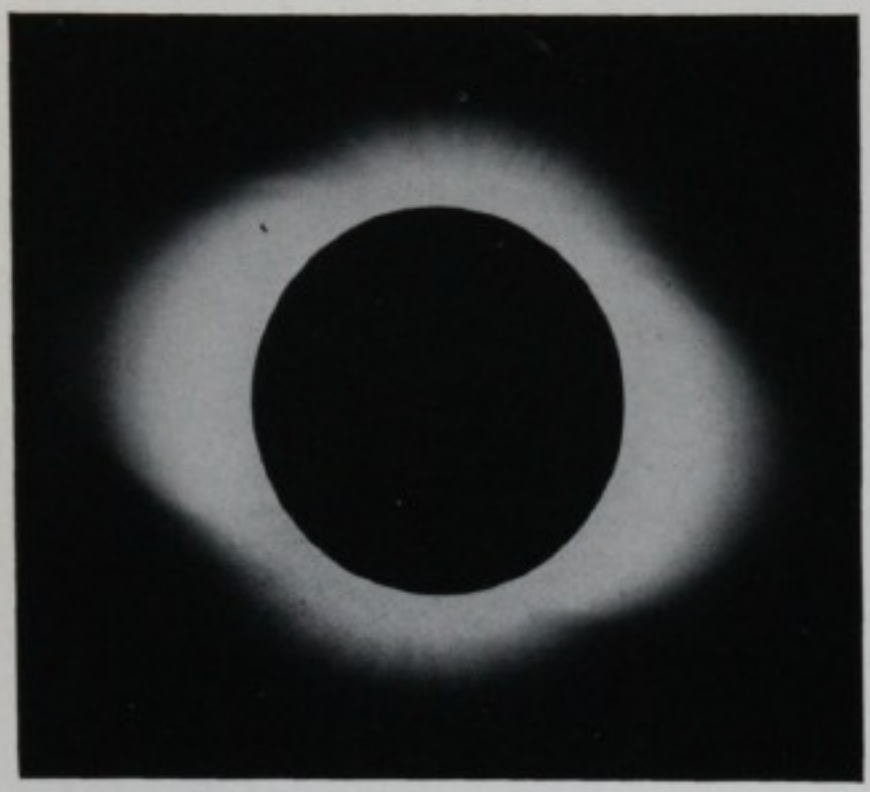
SCHEDULE: Daily (except Monday and Tuesday) at 3:30 and 8:15 p.m.; also at 2 p.m. on Saturdays, Sundays, and holidays. Academy projector. Curator, George W. Bunton.

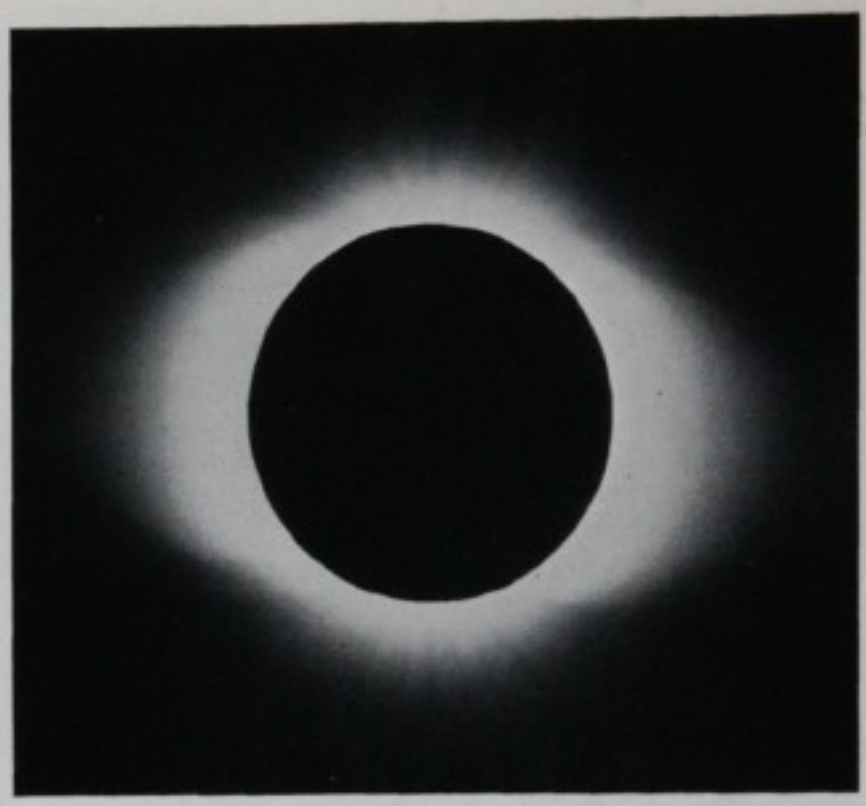
SPRINGFIELD, MASS.: *Seymour Planetarium.* Museum of Natural History, Springfield 5, Mass.

SCHEDULE: Tuesdays, Thursdays, and Saturdays at 3 p.m.; Tuesday evenings at 8:30 p.m.; special star stories for children on Saturdays at 2 p.m. Admission free. Korkosz projector. Director, Frank D. Korkosz.

STAMFORD: *Stamford Museum Planetarium.* Courtland Park, Stamford, Conn.

SCHEDULE: Sunday at 4:00 p.m. Admission free. Spitz projector. Director, Ernest T. Luhde.





These two corona photographs, taken at an interval of 1¾ hours from stations 4,500 miles apart, show that the changes in the sun's outer envelope were at most slight during that time. The corona was photographed (left) at Holmhaeller, Sweden, by the expedition of the University of Uppsala, led by Dr. Ake Wallenquist. This site, in the southern part of the Baltic island of Gotland, was one of few in the Scandinavian part of the path of totality that had perfect weather conditions. A 12-cm., f/33 horizontal camera was used, with a 50-second exposure, yellow filter, on a III-G plate.

The second picture was obtained at Mellen, Wis., by Kenneth L. Hallam and John Bahng, student members of the Washburn Observatory's eclipse expedition. They used a 3-inch telescope with Super XX film and a medium yellow filter; their exposure was ¼ second. North is at the top in both pictures.

Notes on the Eclipse--II

Expedition Blackout

OUR expedition of six observers included five members of the observing group of the Amateur Astronomers Association in New York City. We arrived at Ironwood, Mich., on June 28th, and selected the Gogebic County airport as our observing site. The purpose of the expedition was to take still and motion picture photographs in color and black and white, and to make visual observations of the corona. The table, page 420, lists our equipment, most of which is shown in the photograph.

During our final practice sessions on June 29th, a minor catastrophe occurred —it rained. The equipment, which had been set up on the lawn of our motel, was immediately and frantically moved to a convenient, empty carport. Furthermore, the evening weather report was unfavorable, which considerably lowered our spirits.

We loaded the equipment and left for the airport at 2 a.m.; upon our arrival the dawn was already breaking. Careful study of a cloud bank on the eastern horizon showed that it was receding very slowly, much to our relief. The sun rose above the low clouds at 4:23, showing a small nick in the upper right-hand corner, and after that we viewed the entire eclipse under perfect conditions.

At 4:55, the sun was over 90 per cent covered, and weird color effects began to occur. The sky light was definitely reduced now, appearing a greenish-blue at the horizon and shading into steely blue higher up. The grass appeared a very odd yellow green. There was considerable dew, and ground fog was present in a nearby field.

Then everything seemed to happen so rapidly that it was almost impossible to keep track of all the activity. All the observers were at their instruments as the crescent rapidly narrowed to a sliver and the sky darkened quickly. The crescent reduced to an arc of 40 degrees and suddenly, as the last sunlight disappeared, the diamond ring burst forth and remained visible for about three seconds. Baily's beads were not viewed by anyone. The inner corona appeared about three seconds before totality as a narrow ring; then the outer corona became visible. The spectacle seemed exceedingly large with the naked eye, appearing as would be expected with a pair of binoculars.

The equatorial streamers of the outer corona extended over two lunar diameters on either side, making an angle of 45 degrees to the horizon. The polar brushes were quite short, the larger ones away from the poles slightly curved. The inner corona was silvery-white, the outer corona ashy-white. Two pink prominences were observed with the naked eye, nearly opposite each other,

Edward Oravec operates the Graflex attached to Expedition Blackout's 5-inch, f/29 eclipse camera.

but with 10 x 80 binoculars four prominences were seen.

During totality, the moon appeared a slate blue, the same as the sky around it but much darker. The sunlit sky was seen low in both directions at right angles to the sun, appearing yellowish near the horizon. The shadow cone, steel-blue, tapered to a base about 30 degrees in width at the horizon below the sun. The general illumination was dark but considerably brighter than that of a full moon; it was difficult to read the dial of a camera during totality.

Returning to our lodgings later in the morning, elated at our success, we dropped into bed for some much-needed sleep, except for one C. Cuevas, who began developing and printing eclipse photographs in an improvised darkroom.

The inner corona was photographed successfully, as were the four prominences, the diamond ring, Baily's beads, and the polar brushes. During observations, some difficulties were encountered with two of the instruments.

Other astronomical highlights of Expedition Blackout were visits to Leslie C. Peltier, in Ohio, the Yerkes Observatory, the Adler Planetarium, the University of Michigan Observatory, and our attendance at the Madison convention.

William H. Glenn
and Edward Oravec
Amateur Astronomers Association

Flight from New York

I WAS AMONG the photographic crew on the American Airlines-Hayden Planetarium expedition, 12,500 feet over dense clouds above Rupert House, Que., at eclipse time. From our altitude, and in perfectly clear skies, most striking to me was the immense spread of the corona. The color was a definite steel blue. We flew on a north-northwest course across the path of totality, watching and filming from the openings left by the removal of three escape hatches on the starboard side of the plane. The moon's shadow appeared like an immense hammock beneath us, extending down onto the cloud horizon.

The cloud effects below us were fascinating. Lighting hues progressed from yellow-white through rose; then, as the sky darkened considerably, dark blue and purple with golden sun highlights toned the rolling cloud layer. Finally, during totality, there was an eerie dim gray.

Peter A. Leavens
66 Silver Lane
Oceanside, N. Y.

PROGRAM OF EXPEDITION BLACKOUT

Instrument	*Operated by*	*Film*	*Exposure*	*Pictures during totality*	*Remarks*
Bolex movie camera with 12" f/5.6 telephoto lens	C. Cuevas	16-mm. Kodachrome	8 f.p.s. (1/20 sec.)	12 feet	Some corona, 4 prominences visible; diamond ring at both contacts
GSAP battery-driven movie camera	E. Haupt	16-mm. Super XX	16 f.p.s. (1/45 sec.)	30 feet	
6" reflector, f/6, with Kine Exakta at prime focus	E. De Gennaro	Plus X	1/25 sec.	4	Corona, diamond ring, Baily's beads photographed
Primaflex camera with 20" telephoto	K. Weitzenhoffer	Plus X	1/25 sec.	1	**Film buckled**; camera jammed
5" lens, 12-foot long-focus camera working at f/29	W. Glenn and E. Oravec	Royal Pan	1/4 to 1/2 sec.	9	Some negatives trailed

Balloon Observations

PHOTOGRAPHY of the solar corona from very great elevations — well above the lower layers of the atmosphere that are responsible for most of the scattered light of the sky — was attempted at this eclipse for the first time. Under the sponsorship of the Office of Naval Research, a Winzen Research Skyhook balloon was launched from Fleming Field, South St. Paul, Minn., carrying a battery of automatically operated still and movie cameras. To point at the sun, the cameras were oriented in a precomputed direction, and were mounted on a gyromagnetically stabilized platform. Both black-and-white and color photographs of the totally eclipsed sun were secured at 44,000 feet, and the partial phases were recorded at elevations up to 70,000 feet.

Shown here as it was set up on eclipse morning at Ironwood, Mich., Expedition Blackout's equipment included, from left to right: a Primaflex camera with a 20-inch telephoto lens; a 6-inch reflector fitted with a Kine Exakta camera; the 12-foot camera that is shown in part on the preceding page; a movie camera and 10 x 80 binoculars; a 3-inch refractor for visual work; and a 16-mm. battery-driven movie camera.

The giant Skyhook balloon launched by U. S. Navy scientists 2½ hours before sunrise, to photograph the corona from the stratosphere, is here shown being inflated. The cameras were carried on the platform in the right foreground. Photograph by Minneapolis Morning Tribune.

Adverse wind conditions caused a last-minute move from the planned launching site at St. Cloud, Minn., and the delay prevented attainment of the proposed 90,000-foot altitude.

The balloon was tracked from a plane flying at 5,000 feet, which photographed the dropping of the parachute that carried the cameras safely to earth. Preliminary inspection of the films indicates that the sun remained safely within the field of view of the cameras, 14 degrees in diameter. This success is of considerable importance, as it opens possibilities for other kinds of astronomical observations from high-altitude balloons.

Simultaneously with the Skyhook ascent, a Banshee jet fighter was used to obtain motion pictures of totality from 50,000 feet. These pictures showed some blurring, because of plane vibration.

Shadow Band Observations

RICHARD L. FELDMAN, of Falls Church, Va., set up apparatus at Houghton, Mich., to study shadow bands. These elusive dark bands appear several minutes before and after totality, and move with speeds as great as 10 miles per hour, or about 15 feet per second. Often they are much slower, or even stationary.

To record the light fluctuations caused by the shadow bands, motion pictures are inadequate because of their intermittent nature. Mr. Feldman obtained from the Times Facsimile Corporation an RG facsimile recorder, such as is used in the transmission and reception of weather maps. It has a drum six inches in diameter driven by a synchronous motor, which carries the recording paper through one revolution of 19 inches each second. The record is made on special papers by a glowing stylus which lightly scorches the paper. The recorder is customarily fed by an audio-oscillator of 1,800 cycles per second, modulated by the fluctuations of a photocell. Mr. Feldman made a 1,568-cycle oscillator that was approved by the Washington office of the corporation.

During shipment to Michigan, however, the equipment was slightly damaged, and the apparatus would not work. The weather was bad, and Mr. Feldman writes, "Nature's perversity was a kindly veil for my frustration."

The Virginia amateur had alerted other observers along the path of totality to watch for shadow bands. On Iceland, Air Force officers tried unsuccessfully to see them, but Major Lewis J. Neyland, commanding Detachment 25, 5th Weather Group, transmitted an observation by Mr. Jonsson, a weather forecaster at Reykjavik.

He saw the bands continuously from five minutes before to five minutes after totality, on a light-colored cement driveway. The principal bands were wavy, 10 to 15 feet from crest to crest, and separated by about three feet. They were oriented NNE-SSW, and traveled eastward about 10 miles per hour. Each principal band was about a foot wide, containing many ripples slanted at an angle to the north-northwest. These small bands moved southward, that is, along the lengths of the principal bands, at about six to eight meters per second. Mr. Jonsson actually noted little or no motion, but other observers gave these facts concerning the motions. Mr. Jonsson had not been prepared for the observation, as no instructions had been given to him.

Shetland Islands

THE British Astronomical Association party in the Shetland Islands observed from Saxa Vord, a hill 934 feet high on the northern part of the island of Unst. We had very bad weather conditions and got no results of importance.

We were a varied party, mostly amateurs, from all parts of Great Britain. We had planned mainly photographic observations, and were also acting as a land station for the party, under James Paton, on the aircraft with the Astronomer Royal, Sir Harold Spencer Jones, who was searching for daylight aurorae. We had specially made interference goggles (which have proved very valuable in seeing aurorae in a rather bright sky) and we hoped to measure accurately the position of any aurora seen.

The observers on the plane had fine conditions, but saw no northern lights even though they were almost exactly on the intersection of the maximum auroral zone and the path of totality (63° north, 25° west). The corona and sky were much brighter than expected; this, together with the present minimum solar activity, may account for the invisibility of the aurora.

One of the U. S. Air Force observing stations, under Dr. Peter van de Kamp, was quite near the small pier from which our ferry crossed to Unst. The Americans received visitors and showed us their equipment.

N. G. Matthew
The Observatory, Calton Hill
Edinburgh, Scotland

A SMALL PARTY did not join the main BAA group on Saxa Vord (see above), because on eclipse morning there was a high wind from the southwest and low clouds on the summit. We were guests of Mr. and Mrs. William Sinclair, whose house on Unst is the most northerly in the British Isles. On our host's advice, we decided to stay near sea level. We joined a fellow member of the BAA, Dr. R. H. G. Lyne-Pirkis, at an observing post on the headland at Skaw, 200 feet above the sea.

First we saw the sun, but at noon thick clouds and rain squalls blotted

it out, with the wind blowing 60 miles an hour. A minute before second contact a small break gave us a view of the remaining thin crescent. The break spread and we had an uninterrupted view of totality through thin cloud.

Binoculars were used as a monocular with a grating to observe the spectrum, and prominences were observed with a 3½-inch refractor, as well as Baily's beads at both contacts.

During the eclipse the gale howled in our ears and the sea roared in fury upon the rocks. Some 200 gulls wheeled screaming around our heads. Never was a total eclipse staged in more dramatic setting.

KENNETH BRIERLEY
and G. C. MARLOWE
Manchester Astronomical Society

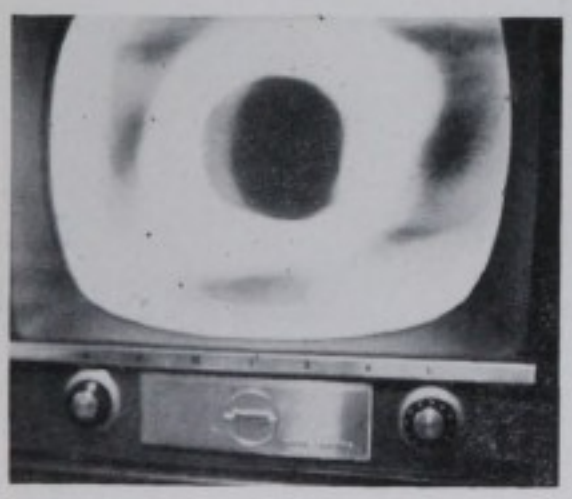
When the eclipse was nearly total, sunlight filtering through tree branches cast these crescent-shaped images on the wall of a house. Minneapolis Star photo.

OBSERVING BY TELEVISION

MODERN SCIENCE enabled millions of people to see the total eclipse from outside the path of totality. I "observed" from Cambridge, Mass. Through the co-operation of the special events department of the Columbia Broadcasting System, the eclipse was televised live from Minneapolis.

At 6:35 a.m. EDT, CBS was already on the air. I hurriedly set up a camera, and took a television picture of the rising sun, partially covered by the moon, at 6:40. The eclipse was not on the screen all the time; at first it was shown for about one minute at five- to 10-minute intervals, interspersed with views of the city and the crowds out to watch. Filmed explanations were put on, and Dr. W. J. Luyten, of the University of Minnesota, gave demonstrations with a small orrery. The eclipse path, plotted on a globe of about four-foot diameter, was shown. The broadcast at one time was from the Empire State building in New York, but except for that one view of the beginning of the partial eclipse there, the cameras televised from the Minneapolis area.

The quality of the picture was good, although technical difficulties occasionally caused flop-over, and the contrast was hard to control. Most of the time, the sun was overexposed. However, the progress of the eclipse could be easily followed. As the climax came, a weak diamond ring was seen just before the sun disappeared. But almost immediately the filters were removed, and the coronal streamers became visible. It was gratifying later to see that newspaper pictures of the corona agreed well with what we had seen over the air. The picture at totality was weak, but still a beautiful sight.



Robert Cox's eclipse expedition was to his living room, where he photographed the corona on the screen of his 21-inch television set.

The image on the screen covered more than half its width. I took photographs using a 120 roll-film camera set at f/4.5, at four feet, with exposures varying from 1/5 to one second, on Super XX film.

ROBERT E. COX
32 Shepard St.
Cambridge 38, Mass.

Brooklyn Center, Minn.: Some 75 members and friends of the Amateur Astronomers Association traveled from New York City to an observing site on U. S. route 52, about five miles northwest of Minneapolis, in the small community of Brooklyn Center. Five of the group, which was under the chairmanship of George V. Plachy, secretary of the society, arrived on June 26th by airplane. The site had been selected in April by Dr. C. S. Brainin, former AAA president.

Each day's work of setting up and testing equipment began at 4 a.m. and usually ran well into the night. On eclipse morning all were on hand at 2:30. A 10-foot camera and a 16-mm. movie telephoto camera to record the complete eclipse were among the instruments used. Several of the group's black and white pictures were published in the July 26th issue of *Life* magazine.

Pikes Peak, Colo.: Although the eclipse was well publicized in the local newspapers, writes P. H. More, of Colorado Springs, only three cars were on the summit of Pikes Peak at sunrise, probably because of the rainstorm during the preceding night, and the heavy fog that enveloped the mountain until about 3:45 a.m. Mr. More photographed the partially eclipsed sun through broken overcast at 4:37 a.m. MST, and notes that the picture compares closely with the third last exposure in the series by Roy Swan on page 331, August issue, taken at 5:43 CST in Minneapolis.

Kiev, Ukraine: According to the Paris daily paper, *Le Monde*, of July 2, 1954, favorable weather conditions aided observations of the eclipse at Kiev, capital of the Ukraine, and at several other stations in the U.S.S.R. The Russian astronomers were accompanied by scientists from China, Czechoslovakia, East Germany, Hungary, and Poland.

Galtoe, Sweden: The Berlin amateur astronomers society, Vereinigung der Sternfreunde, was fortunate in sending its expedition to Galtoe, one of the few Swedish stations not hampered by clouds.

Their photograph of the corona in red light, exposed for eight seconds with an 80-mm. refractor, shows the western coronal streamer clearly double, at distances greater than two solar diameters from the sun's center.

Kragenaes, Sweden: Successful eclipse observations, both visual and photographic, were secured at a point close to the intersection of the central line with the west coast of Sweden. The party consisted of R. Fogelquist, Miss E. Olsson, and U. Linderoth, students at the University of Uppsala.

The principal instrument was a coronal camera of 25 inches focal length, mounted on a clock-driven 6-inch reflector. Eleven plates and several meters of motion picture film were exposed. This material will be used for a photometric study of the corona.

American Astronomers Report

Here are highlights of some papers presented at the 91st meeting of the American Astronomical Society at Ann Arbor, Mich., in June. Complete abstracts will appear in the Astronomical Journal.

Solar Magnetic Fields

The solar magnetograph of Drs. Harold D. and Horace W. Babcock, Mount Wilson and Palomar Observatories, has been in operation for two years. They reported a study based on a sequence of 360 magnetograms, on each of which can be measured the location, polarity, and intensity of widespread weak fields on the sun apart from sunspots. The detector, responding to the component of the field in the line of sight, indicates fields as small as a fraction of one gauss.

All of the surface fields are found to have a fine structure, with local fluctuations in time that suggest a close connection with turbulent elements in the photosphere.

The main dipolar or "general" field of the sun, of average intensity one or two gauss and with polarity opposite to that of the earth, is usually limited to solar latitudes greater than 60°, but shows irregular fluctuations of intensity and extent. The total flux of the main field is estimated to be 3×10^{21} maxwells, but in August, 1953, the north polar flux appeared to be two or three times as great as normal. The polar magnetic fields occur in regions from which the coronal features known as polar tufts or plumes are seen to originate on eclipse photographs.

No evidence has been found for inclination of the magnetic axis to the axis of the sun's rotation.

Most of the prominent magnetic areas in latitudes below 50° north and south are bipolar; sunspots may or may not occur within them. If their intensity is greater than one gauss, they show a close identification with bright calcium flocculi or plages on spectroheliograms. Their magnetic polarities obey the laws of polarity found by Hale for sunspots.

The archlike patterns of bright coronal radiations are located above the stronger bipolar magnetic regions; these fields seem to extend at least as far vertically as they do horizontally over the sun's surface.

Newly found by the magnetograph are unimagnetic regions, in which the fields are predominantly of one sign, and in such cases it is not at all obvious where the emerging magnetic flux returns to the sun. They are not related to other surface features, corona or prominences, but one such field, first seen on August 20, 1953, was observed on six successive rotations of the sun, each rotation averaging 27 days. About three days after each of five of the returns to the central meridian of the sun, the unimagnetic field was followed by a terrestrial magnetic storm of a well-recognized 27-day sequence. The Babcocks suggested tentatively that the heretofore hypothetical "*M*" regions (Bartels, 1932) that are believed to be sources of solar corpuscular streams may be these unimagnetic fields.

The magnetic pattern of the sun shows very considerable changes from day to day, and there is evidence for appreciable fluctuations in detail, of the order of one gauss, in intervals of 30 minutes. Such fluctuations are plausibly related to rather large-scale turbulence of the photospheric material; hence, fluctuation of radial velocities may be expected. The magnetograph can be readily converted to measure the Doppler effect to an accuracy of 10 meters per second. Preliminary results indicate that differential velocities of the order of 100 meters per second are characteristic of areas 15,000 kilometers in extent.

Distances of Galaxies

Uncertainties in the distances of extragalactic nebulae arise from our estimates of their brightnesses, from the unknown absorptions of their light, and from other factors. At the Lowell Observatory, Dr. Albert G. Wilson has sought a way of determining a galaxy's distance without reference to its apparent luminosity. In some respects his method resembles that by which the dynamical parallax of a double star system is found. It can be applied to spiral nebulae of types Sa and Sb, similar to the Andromeda system, M31.

He bases his calculations on the apparent ellipticity and the observed rotational velocity of each system, but it is necessary to introduce the assumption that giant Sa and Sb galaxies have densities equal to that of our own Milky Way. This assumption is found to be reasonable because the resulting distances are in agreement with those determined by other methods.

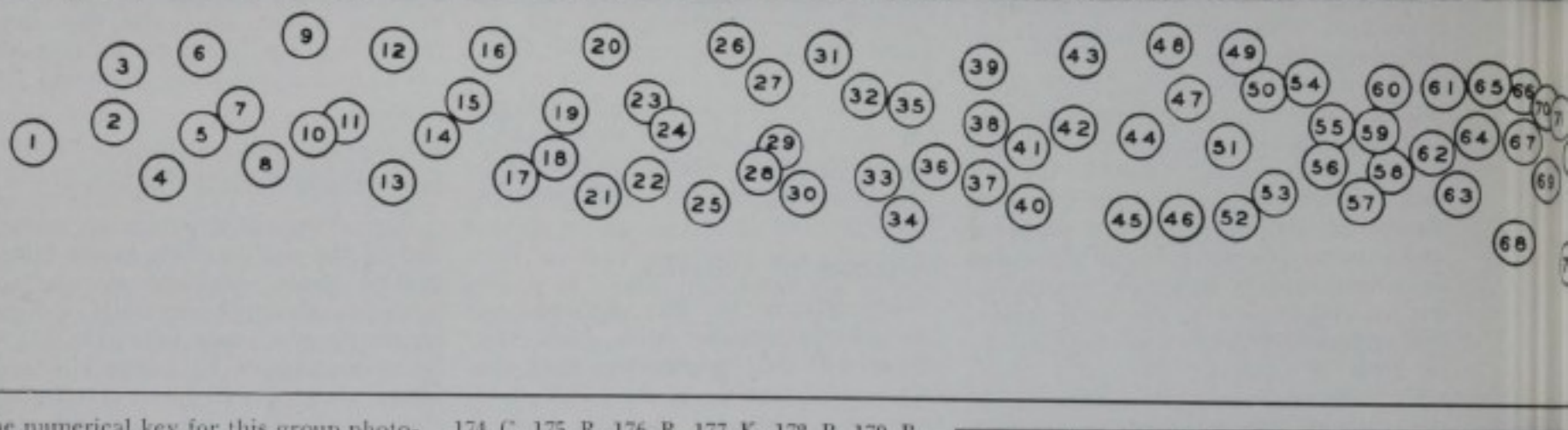
For M31 Dr. Wilson obtains a distance of 487,000 parsecs, which is within three per cent of Baade's corrected photometric value of 501,000 parsecs (about 1,630,000 light-years). For the system NGC 4594 in the Virgo cluster of galaxies, the result is 5.2 million parsecs, in accord with Baade's tentative correction of −2.1 magnitudes for the absolute magnitudes of galaxies beyond the local group. This would suggest that the −1.4 correction and the 1952 "doubling" of the scale of the universe is not final and that larger corrections are likely to be necessary. (See *Sky and Telescope*, June and July, 1953.)

Rice-grain Observations from High-altitude Balloons

The rice-grain structure or granulation of the sun's surface might best be studied from high-altitude balloons carrying telescopes especially designed for the purpose, according to Dr. Martin Schwarzschild, of Princeton University Observatory. Pointing out that we have observed the sun's granular surface for very many years, but still know little about it, Dr. Schwarzschild expressed doubt that earth-bound telescopes would ever be able to observe through the atmosphere sufficiently well to solve the riddle of the rice grains.

Therefore, he suggested that American astronomers take up instrumentation such as has already begun at Cambridge, England, to fit a camera having an effective focal length of about 200 feet into a length of about 10 feet. This folding of the camera would have to be achieved by optical means, probably requiring combinations of lenses and

Left to right are Drs. J. W. Evans (Sacramento Peak Observatory), R. L. Hardie (Lowell Observatory), A. N. Cox (Los Alamos Scientific Laboratory), and I. King (U. S. Navy), at the Ann Arbor meeting of the American Astronomical Society. University of Michigan photograph.



The numerical key for this group photograph is simplified to show the last-name initial of each person; to identify a familiar face, it is necessary only to peruse the names with that initial letter in the alphabetical list. The presence or absence of persons known by name can be checked quickly in the alphabetical list. Readers who find this method of listing more generally useful than previous keys should let us know by postcard. — ED.

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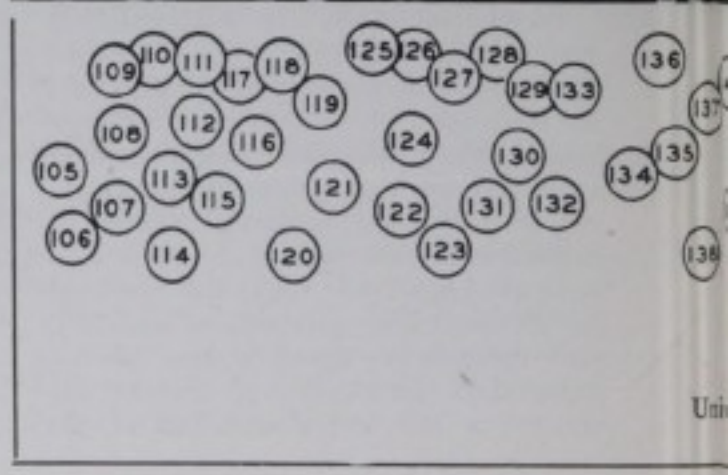
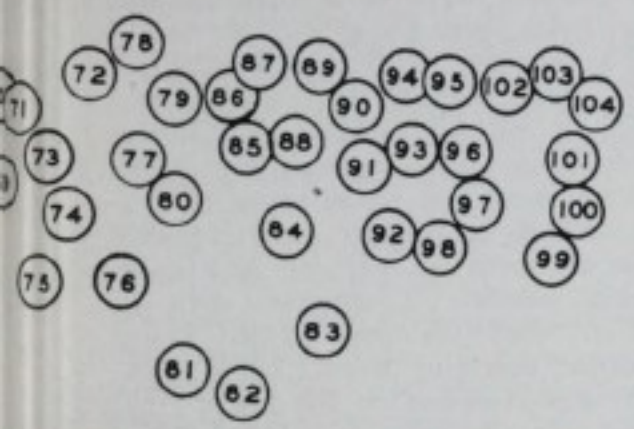
147, O. Gingerich, H; 129, Miss G. Gjelle-





stad, Oslo University, Norway; 33, J. Gleim, N; 193, L. Goldberg, M; 198, Mrs. Goldberg; 200, David Goldberg; 197, Edward Goldberg; 196, Susan Goldberg; 36, Mrs. F. Goddard, Ann Arbor, Mich.; 1, G. Grant, M; 51, J. Greenstein, MWP; 135, R. Grenchik, I.

169, F. Haddock, NRL; 134, J. Hall, N; 195, R. Hardie, Lowell; 114, Miss M. Hardy, N; 158, H. Hartzler, Goshen College; 86, Miss M. Hazen, M; 150, D. Heeschen, H; 130, H. Helfer, Carnegie Inst.; 115, K. Henize, M; 107, Mrs. Henize; 152, Mrs. A. Henry, Brooklyn College; 106, Mrs. N. Hepburn, NRL; 31, P. Herget, Cincinnati; 46, H. Hertz, N; 170, R. Hide, Ye; 148, Mrs. H. Hogg, David Dunlap; 180, M. Huffer, W; 143, M. Humason, MWP.

48, J. Irwin, I.

77, L. Jacchia, H; 116, Miss D. Jehoulet, Liege, Belgium; 63, A. Joy, MWP; 74, Mrs. Joy; 70, J. Jugaku, M.

93, F. Kameny, Steward; 2, E. Kane, Detroit Edison Co.; 117, P. Keenan, P; 20, G. Keller, P; 80, I. King, U. S. Navy; 177, H. Ko, Ohio State; 173, J. Kraus, Ohio State; 61, W. Krogdahl, Dearborn; 59, Mrs. Krogdahl; 69, G. Kron, L; 68, Mrs. K. Kron, L; 119, R. Kulsrud, Ye.

191, W. Liller, M; 188, Mrs. Liller; 91, E. Lilley, H; 18, Miss H. Losh, M; 50, J. Lund, Naval Ordnance Lab.

99, Mrs. H. Malitson, NRL; 98, I. Malitson, Nat'l. Bureau of Standards; 39, T. Matthews, H; 113, Mrs. M. Mayall, AAVSO; 41, J. McAnally, Washington, D. C.; 43, S. McCuskey, WS; 185, Miss J. McDonald, Dominion Astrophysical; 19, Miss C. McGregor, N; 167, D. McLaughlin, M; 156, Mrs. McLaughlin; 47, G. McVittie, Illinois; 166, A. Meinel, Ye; 25, E. Mendoza, Ye; 57, D. Menzel, H; 6, Mrs. Menzel; 3, Miss E. Menzel; 73, J. Merrill, P; 45, Miss B. Middlehurst, St. Andrews University, Scotland; 62, A. Mikesell, N; 76, Kathryn Mikesell; 75, Margaret Mikesell; 182, F. Miller, M; 8, J. Milligan, M; 199, O. Mohler, McM; 138, Mrs. Mohler; 163, W. Morgan, Ye; 38, Miss E. Mueller, M; 30, P. Mutschlecner, I.

21, J. Nassau, WS; 151, Mrs. Nassau; 144, G. Newkirk, SP; 7, Mrs. J. Newkirk, M.

165, J. O'Keefe, Army Map Service; 124, K. Osawa, Ye.

35, J.-C. Pecker, HA; 178, K. Pierce, McM; 105, S. Plakidis, National Obs., Athens, Greece; 160, G. Preston, Army Map Service; 161, Mrs. Preston; 16, W. Protheroe, P.

194, I. Rabinowitz, Knolls Atomic Power Lab.; 192, Mrs. Rabinowitz; 37, R. Rhynsburger, N; 179, P. Riggs, Drake; 176, Miss M. Risley, Randolph-Macon; 84, J. Robertson, N (ret); 175, L. Robinson, Wright-Patterson AFB; 90, Miss N. Roman, Ye.

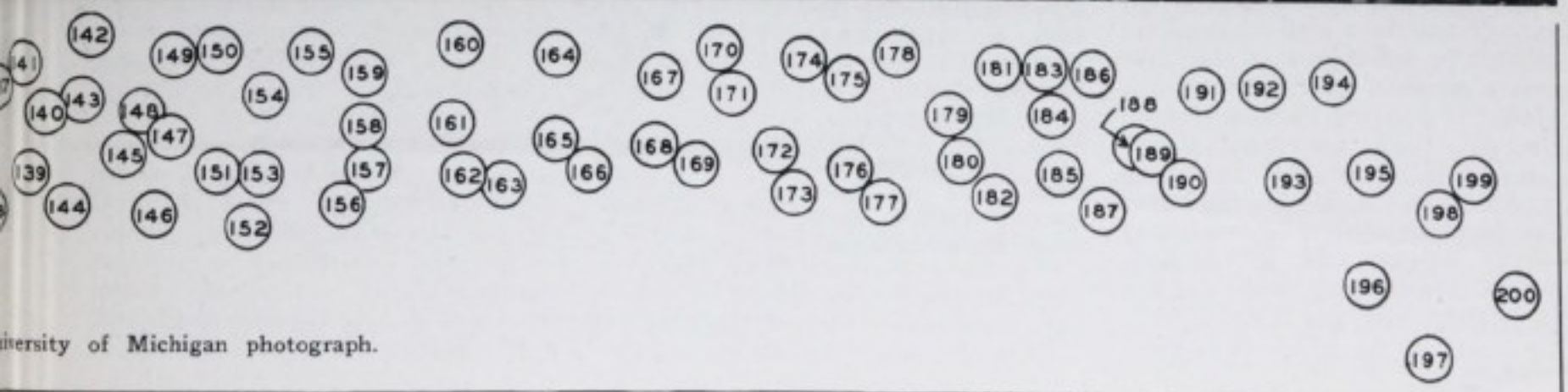
128, A. Sandage, MWP; 109, M. Savedoff, University of Rochester; 53, A. Schlueter, Goettingen, Germany; 58, M. Schwarzschild, Pr; 56, Mrs. Schwarzschild; 71, R. Sears, I; 189, C. Seyfert, Dyer; 72, E. Spiegel, M; 181, A. Spitz, Spitz Labs.; 79, B. Stroemgren, Ye; 112, Miss H. Steinman, Ye; 125, J. Stock, WS; 127, Mrs. Stock; 132, O. Struve, Leuschner; 22, Miss H. Swope, MWP.

87, R. Tayler, Pr; 139, Miss E. Tilley; 95, C. van Houten, Ye.

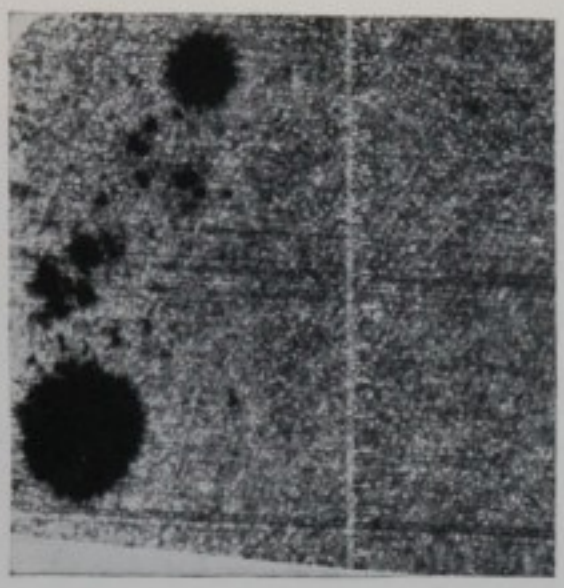
65, J. Waddell, M; 184, N. Wagman, Allegheny; 13, M. Walker, MWP; 146, Mrs. C. Warwick, SP; 145, J. Warwick, SP; 123, Mrs. A. Wehlau, WS; 10, W. Wehlau, WS; 149, E. Weston, M; 15, Miss L. Weston, N; 40, A. Whitford, W; 85, F. Whipple, H; 92, Mrs. Whipple; 159, C. Whitney, H; 168, R. Wildt, Y; 186, H. Williams, Spitz Labs.; 60, R. Williamson, Los Alamos; 142, R. Wilson, University of Louisville; 126, Miss H. Wright, MWP; 67, M. Wrubel, I.

157, K. Yoss, Louisiana State; 89, H. Zirin, H; 32, unidentified.

H, Harvard; HA, High Altitude; I, Indiana; L, Lick; M, Michigan; McM, McMath-Hulbert; MWP, Mount Wilson-Palomar; N, Naval Observatory; NRL, Naval Research Laboratory; P, Perkins; Pr, Princeton; SP, Sacramento Peak; W, Washburn; WS, Warner and Swasey; Y, Yale; Ye, Yerkes.



iversity of Michigan photograph.



Solar granulation and sunspots, photographed by P. C. Keenan with the Yerkes Observatory 40-inch refractor.

mirrors in systems of special design.

Balloons that can carry a payload of 1,000 pounds at heights of 50,000 feet are now available. With practically all of the atmosphere below such heights, the apparatus would be employed to take short-exposure photographs of the sun's surface. It should reveal the fine detail in the sun's dark and bright granulations, which are now observed only in their coarser aspects.

Dr. Schwarzschild has determined that the intensity of the boiling or turbulence that causes the solar granulations increases with diminishing size of the granules. From wave lengths of turbulence as long as 10,000 kilometers, the intensity was found to increase steadily to the observing limit of 2,000 kilometers, beyond which it was not possible to measure the granulations because of lack of definition on even the best Mount Wilson Observatory solar photographs.

The Princeton astronomer said, "The fact that the latest analysis indicates a steadily rising amplitude for shorter and shorter wave lengths as far as we can observe makes one highly suspicious that thus far we have never yet seen the most important part of the granulation, which might consist of elements as small as 300 kilometers in diameter."

Red Stars at the Center of the Galaxy

NGC 6522 is a globular cluster that is embedded in the central bulge of our galaxy. It acts as a kind of guidepost to other types of objects in that very important region of space. For instance, at Mount Wilson and Palomar Observatories, W. Baade has found a concentration of short-period pulsating stars (RR Lyrae variables) in the region surrounding this cluster. They showed maximum numbers at an apparent brightness corresponding to the distance of the galactic center, and indicating that at the center of the Milky Way these stars had their greatest concentration.

Now, at the Warner and Swasey Observatory of the Case Institute of Technology, Drs. J. J. Nassau, V. M. Blanco, and S. W. McCuskey have recently studied the surroundings of NGC 6522 with infrared objective-prism plates taken by Dr. G. Haro, at the National Astrophysical Observatory, Tonanzintla, Mexico. These plates, made with a large Schmidt telescope, especially record stars of type *M*, which appear red to the eye and have their maximum energy output in the infrared.

The Case astronomers found 213 stars of class *M* within 11.2 minutes of arc of the cluster, some of them so faint as to be certainly well beyond the center of the galaxy. As with the RR Lyrae stars, these *M* stars show a marked concentration at the apparent magnitude which for them corresponds to the distance of the galactic center. In a unit volume of space there, they seem to be about four times as numerous as the RR Lyrae stars. By contrast, other studies have shown that in the vicinity of the sun the ratio is 3,000 *M* stars to one RR Lyrae-type star.

The discrepancy is believed to be caused by the difference in the distribution of these two types of stars in the galaxy as a whole. The *M* stars are part of a very flattened ellipsoid that is concentrated in the plane of the galaxy and that extends to distances from the center well beyond the sun. The RR Lyrae stars form a spheroidal system in which the density at the sun's distance is very low.

Star Cluster NGC 2264

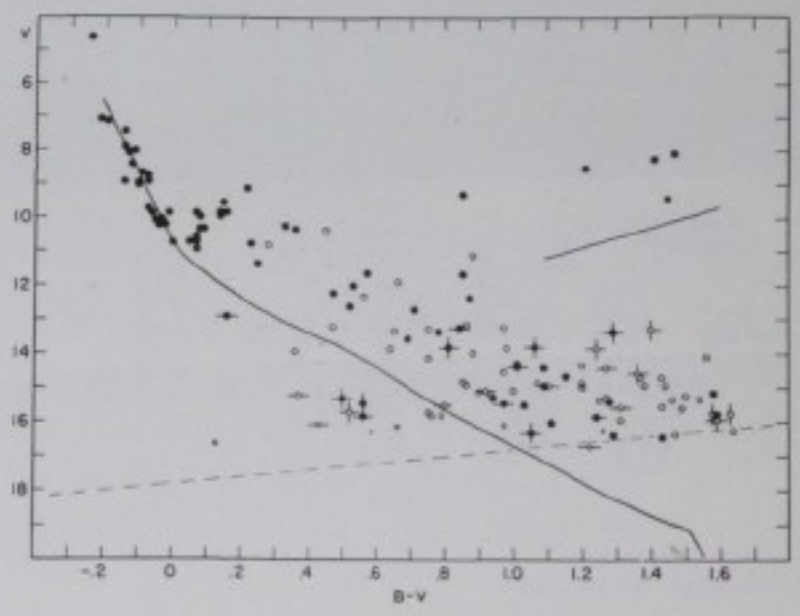
The nebulous open cluster NGC 2264, which surrounds the 5th-magnitude *O*7 star S Monocerotis, is peculiar in containing not only *O* and *B* stars but also many faint variables with emission-line spectra which are presumably T Tauri stars. The magnitudes and colors of stars in this cluster have been measured by Dr. Merle F. Walker, Mount Wilson and Palomar Observatories. His three-color photoelectric observations with the 60- and 100-inch reflectors, supplemented by photographic photometry with the 60-inch, have not been entirely reduced, but already they point to some remarkable properties of the cluster.

In the accompanying diagram, Johnson and Morgan's normal main sequence is indicated by a heavy line. This has been fitted to the stars in the upper left portion of the diagram, giving a distance of 3,900 light-years for the cluster, after allowance is made for interstellar absorption of light.

Fainter stars of the cluster deviate from the normal main sequence in a striking manner. At color index +0.1, corresponding to spectral class *A*0, the observed sequence rises by about 1½ magnitudes; for stars redder than this, to the right, there is a band of points about two magnitudes in width and about two magnitudes above the main sequence. At its lower end, this band has widened until some stars lie six magnitudes above the main sequence.

The presence of *O* and *B* stars in NGC 2264 indicates that this cluster is only a few million years old. Theoretical studies have suggested that stars of small mass that are so young as this may still be contracting gravitationally from the prestellar medium; such stars should populate a sequence with a smaller slope than the normal main sequence, diverging from it at a point that would depend on the age of the group. If the point is taken in this case to be at spectral type *A*0, then the age of the cluster is a million years, according to the calculations of Salpeter.

Another curious feature of this cluster is the existence of five yellow giant stars, which are usually rare in clusters having stars earlier than about *A*0. But stars of this kind would require more than 10^8 years to evolve from main-sequence stars, according to current ideas of stellar evolution. Dr. Walker suggested that these stars, too, may be recently formed objects that appear as yellow giants while contracting to become normal main-sequence stars.



Dr. Walker's plot of magnitude (vertical scale) against color for stars in NGC 2264. Dots are stars observed photoelectrically; circles, photographically. Stars with horizontal bars have bright H-alpha lines in their spectra; vertical bars denote known variables.

NEWS NOTES

By Dorrit Hoffleit

INTERNATIONAL NAUTICAL MILE ADOPTED

When asked the definition of a nautical mile, most of us glibly recite that it is the length of a minute of arc at the equator, or 1/60 of a degree. But this definition has not resulted in the universal adoption of a standard length for the nautical mile.

In 1929, the International Hydrographic Bureau adopted a value of 1,852 meters, but Great Britain, the United States, and Russia each continued to use its own different standard length. Recently, however, the Bureau of Standards announced that as of July 1, 1954, the U. S. Departments of Commerce and Defense have adopted the international nautical mile (1,852 meters or 6,076.1033 feet) in place of the U. S. nautical mile (1,853.248 meters or 6,080.20 feet).

The revision will not affect existing nautical charts or the calibration of navigational instruments. It should aid the reduction of precise measurements for international and global surveys.

TELEVISION ASTRONOMY

From the latest annual report of the Greenwich Observatory we learn that direct telescopic views of astronomical objects have been televised in England. Removing the spectrograph from the Greenwich 36-inch reflector, F. J. Hargreaves replaced it by a BBC television camera. The camera lens was removed and the photocathode was put at the Cassegrain focus. A Barlow lens just inside the focus allowed images to be enlarged up to six diameters. On January 13, 1954, this arrangement gave the television audience fine views of Jupiter and its Galilean satellites, and of the moon.

C. P. OLIVIER RETIRES

On June 30th, Dr. Charles P. Olivier retired as head of the department of astronomy of the University of Pennsylvania. He will continue to serve in an advisory capacity as emeritus professor. His successor is Dr. Frank Bradshaw Wood, associate professor of astronomy since 1950, noted for his work on eclipsing variable stars.

For many years, Dr. Olivier has been president of the American Meteor Society, which has had its headquarters at the Flower Observatory in Upper Darby, Pa. He will continue to carry on the work of the society, moving its files to his home. The new address for members' correspondence and for the reporting of fireballs and other meteor observations is 521 N. Wynnewood Ave., Narberth, Pa.

The Flower Observatory has been given up as an observing site because of city lights and smoke. It is to be replaced by a modern observatory built on a 31-acre tract three miles west of Paoli, Pa. Meanwhile, University of Pennsylvania astronomers continue to use the Cook Observatory, Wynnewood, Pa., bequeathed by Dr. Gustavus W. Cook upon his death in 1940. The 28-inch reflector and the 15-inch horizontal telescope there are scheduled to be moved to Paoli.

TEXTBOOK VARIABLE

Dr. Eric Lindsay, of the Armagh Observatory, in a recent *Irish Astronomical Journal*, reports an unusual accidental discovery of a new variable star. He was examining the two pictures of the expanding nebulosity around Nova Persei on pages 786 and 787 of the textbook *Astronomy*, by Russell, Dugan and Stewart, and noticed that a faint star in the photograph for September 20, 1901, was much fainter in the second picture, dated November 13, 1901.

The star in question lies just below the extreme upper right tip of the nebulosity in the picture on page 786. At Yerkes Observatory, G. Van Biesbroeck checked the original plates, which had been taken there, and some others, confirming the reality of the variation. It is probably that of an eclipsing binary.

RADIO SEXTANT

The Navy Bureau of Ships has already tested on shipboard its first radio sextant, built by the Collins Radio Company, at Cedar Rapids, Iowa. The sextant works by detecting radiation from the sun at a wave length of 1.9 centimeters, chosen because atmospheric absorption at this wave length is low, and it was possible to build a high-quality receiver with a relatively small antenna.

Nevertheless, the radio sextant is not an instrument to be carried around by hand. It looks, superficially, much like any late wartime radar dish, and it requires complex electronic controls. A more recent model operates at only 0.87 centimeter and is capable of minaturization.

For daytime use on shipboard, the radio sextant fulfills the dream of a sextant that works in any weather. At night, it may be possible to use the moon, which gives a weak but steady signal. One of the problems is to determine the effect of atmospheric refraction when the sun is near the horizon; the present model is being used in a series of observations to evaluate the radio refraction effect. Once this work is done, such a sextant on shipboard will provide continuous readings of the sun's altitude and azimuth, thereby permitting a solar fix.

IN THE CURRENT JOURNALS

SCIENCE AND CHRONOMETRY, by Adrien Jaquerod, **Endeavour,** July, 1954. "In any case, chronometry has now reached a turning-point and, although the pendulum and the balance-wheel and spiral-spring can look forward to continued application for everyday measurement of time, they are both almost certain to be ousted for high-accuracy measurements by the tuning-fork clock, and especially by the quartz-crystal clock and that described as molecular or atomic. . . . One is even justified in hoping for important discoveries, perhaps sensational ones, which will compensate us for having to give up the Earth as a time standard."

AN EARLY BUREAU OF LONGITUDE: PEIRESC IN PROVENCE, by Seymour L. Chapin, **Navigation,** June, 1954. "While it had functioned, his plan had produced results in the correction of maps. Even after it ceased, its influence remained, for Peiresc's work was responsible for the beginning of two traditions which were later to bear great fruit; namely missionary observations and scientific expeditions."

WHERE TO DRAW THE LINE, by Warren D. Forrester, **Journal,** Royal Astronomical Society of Canada, July-August, 1954. "Until 1950 only small sections of the northern boundaries of Alberta and British Columbia had been dealt with at all, but . . . a programme . . . has now brought the Alberta and British Columbia boundaries nearly to completion and made a good start on the Saskatchewan boundary. That stars have been able to play a part in this task was due to the boundary having been agreed upon as the astronomically determined sixtieth parallel of north latitude between certain east and west limits."

RADIO OBSERVATIONS OF METEORS, by Peter M. Millman, **Science,** August 27, 1954. "The radio technique of meteor observation enables us to extend the systematic recording of meteor rates down to the 9th or 10th magnitude; to determine satisfactory heights and velocities on a scale previously impossible; to calculate the orbits of meteor showers and individual meteors, in particular those that appear only in the daytime; and to study wind drift and fine structure in the ionosphere. The radio observations have quite definitely indicated that down to the 9th magnitude, corresponding to particles approximately 1 mm in diameter, meteors are members of the solar system and do not come from interstellar space."

ULTRAHIGH TEMPERATURES, by Fred Hoyle, **Scientific American,** September, 1954. "They occur in nuclear explosions and in the interiors of stars. In the latter they promote thermonuclear reactions and perhaps convert hydrogen into all other elements on the periodic table."

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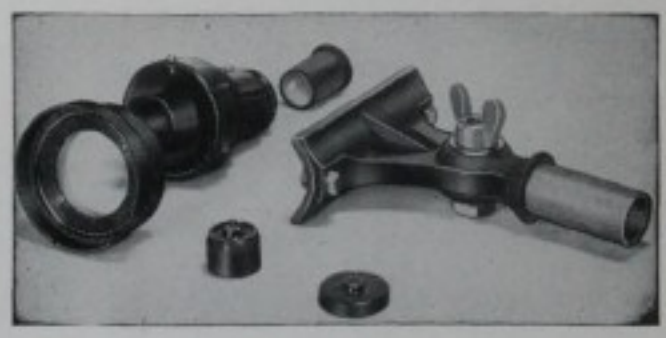

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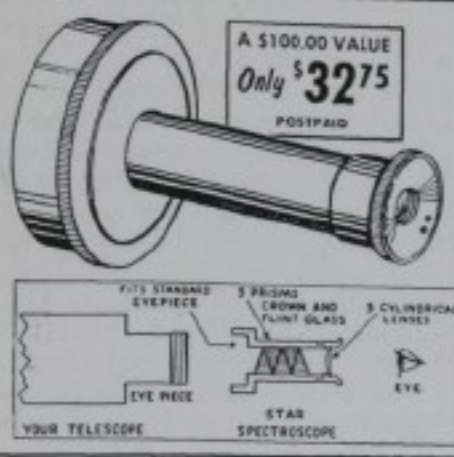

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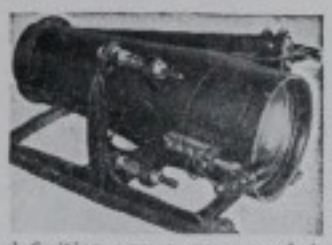

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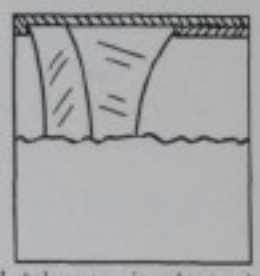

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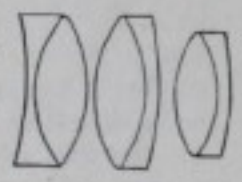

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BOOKS AND THE SKY

OPTICAL IMAGE EVALUATION

National Bureau of Standards Circular 526. U. S. Government Printing Office, Washington, D. C., 1954. 289 pages. $2.25.

SINCE its earliest beginnings, the field of optical design has had one serious handicap: the difficulty, not to say impossibility, of deciding how a new lens design would perform in practice. The process has always been that of working a given arrangement over and over, making differential corrections of curvatures, separations, and other parameters, until the aberrations, as disclosed by ray-trace computations, have been reduced to the minimum. Since there are various interdependent aberrations, the criteria for this minimum are not always clear, and often the labor of getting the best out of a given design makes it advisable to stop when the aberrations have been reduced to a degree which will provide adequate performance.

But the mathematical picture revealed by conventional ray-tracing methods is not directly translatable into a statement of actual performance. In the first place, there is not enough data. For most designs, the tracing of perhaps a dozen rays across the entrance aperture in each of two perpendicular planes, for perhaps five selected object points at different field angles in three colors of light, represents about two weeks of work by an optical computer using a desk calculator such as the Marchant or Fridén. Such a procedure might be applied as a final check on an important new system, but would certainly not be undertaken at each new step in the development of a design. Most lens designs are completed on the basis of only a fraction of this amount of information; yet for a really complete appraisal of the performance of a new system, one should have perhaps a thousand rays traced for each of a dozen image points.

A second important reason is that there is no general agreement or understanding of the relations between the geometrical picture as determined by ray tracing, and the more-or-less subjective concept of performance, as stated in such ill-defined terms as definition, image quality, sharpness, delineation, and the like.

One criterion which has been in wide use is "resolving power," as determined by the ability of a lens to yield distinctly separate images of a bundle of parallel lines. A lens can be tested on an optical bench with a resolving-power target and its resolving power according to this criterion determined (not without considerable disagreement between observers, or on the part of a single observer at different times); and it is possible, on the basis of experience and shrewd guessing, to predict within a factor of two or so the resolving power of a new design from knowledge of the geometrical circle of confusion. But it is becoming clear from wartime work on aerial photographs that resolving-power measurements are not adequate to predict the ability of a lens to define small detail. Contrast is much more important, and contrast and resolving power are not the same thing at all; in fact, the location of the image plane for best contrast is not the same as the location for maximum resolving power.

The last 20 years, however, and especially the last decade, have seen the cracking of this shell of indeterminacy. New mathematical methods, and particularly new electronic and mechanical tools, are helping to make the evaluation of lens performance a matter of precise determination rather than educated surmise. And there has been an accelerated effort among optical people to associate the mathematical optical system with its physical counterpart, that is to say, to

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There are many spiral nebulae in this new list, but this does not limit the celestial variety of the set. There are three instances where they are similar, but not alike. Then, too, eight of these slides are duplicates of some in Slide Set 2, but these are 200-inch photographs that were not available when Set 2 was put on the market; asterisks(*)identify them.

SLIDE SET 4

73—Spiral nebula (Canes Venatici) NGC 4631, edge on
74—Spiral nebula (Canes Venatici) NGC 4244, edge on
75—Spiral nebula (Ursa Major) NGC 2681*
76—Spiral nebula (Canes Venatici) NGC 4736
77—Spiral nebula (Ursa Major) NGC 2976
78—Spiral nebula (Leo) NGC 2903
79—Spiral nebula (Ursa Major) NGC 2841
80—Spiral nebula (Ursa Major) NGC 3031*
81—Spiral nebula (Virgo) NGC 5364*
82—Spiral nebula (Pisces) NGC 628
83—Spiral nebula (Ursa Major) NGC 5457
84—Spiral nebula (Virgo) NGC 4565, edge on*
85—Barred spiral (Coma Berenices) NGC 4314
86—Barred spiral (Ursa Major) NGC 2685
87—Satellite galaxy of M31 in Andromeda, NGC 205
88—Planetary nebula (Hydra) NGC 3242
89—Globular cluster (Serpens) NGC 5904
90—Whirlpool spiral nebula (Canes Venatici) NGC 5194-5195
91—Trifid nebula (Sagittarius) NGC 6514*
92—Ring nebula, planetary (Lyra) NGC 6720*
93—Crab nebula (Taurus) NGC 1952*
94—Horsehead nebula (Orion) Barnard 33*
95—Faint dwarf stellar system (Sextans)
96—Expanding nebulosity around Nova Persei 1901

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develop a satisfactory quantitative description of optical image quality.

The tools, of course, are the digital computers and integrators, which make possible now a high-speed mathematical analysis of an optical system which is sufficiently comprehensive to reveal the detailed structure of a point image. The tracing of a few thousand rays is no longer a fantastic idea. Furthermore, the computers do not balk at the idea of tracing skew rays, which is practically never done in hand computations because of the labor involved. One of the digital computers is now engaged in the task of finding **all** possible useful photographic triplets. This will take a few months, but without the computer the idea would be ridiculous.

Significant new methods based on communications theory — our youngest mathematics — are opening the doors of optics to electronics engineers. Old-line optical designers are somewhat startled to come across such terms as noise, bandwidth, signal, response characteristics, in literature on optical design.

Very little, if any, of this new work has found its way into bound literature; it is scattered profusely, of course, in current periodicals. **Optical Image Evaluation** is a collection of 19 papers, given at the symposium on the evaluation of optical imagery at the National Bureau of Standards in 1951. It is the only compilation on this very new and frequently controversial field, and its price certainly makes it attractive to everyone.

The most significant contributions are perhaps those of Schade, on communication theory and optics, and that of Kingslake, who discusses the rather complex problem of deciding where the lens should be focused. The paper by Macdonald presents criteria of lens performance on an objective basis; and papers by Howlett, Arnulf, and Ingelstam discuss test procedures in use at foreign laboratories.

All the articles are excellently written, and are of importance; another reviewer might well have selected a different group for mention. There are included in the book the discussions from the floor that took place after each paper. Much of the book is quite heavy — necessarily so — and it will not appeal to the casual reader.

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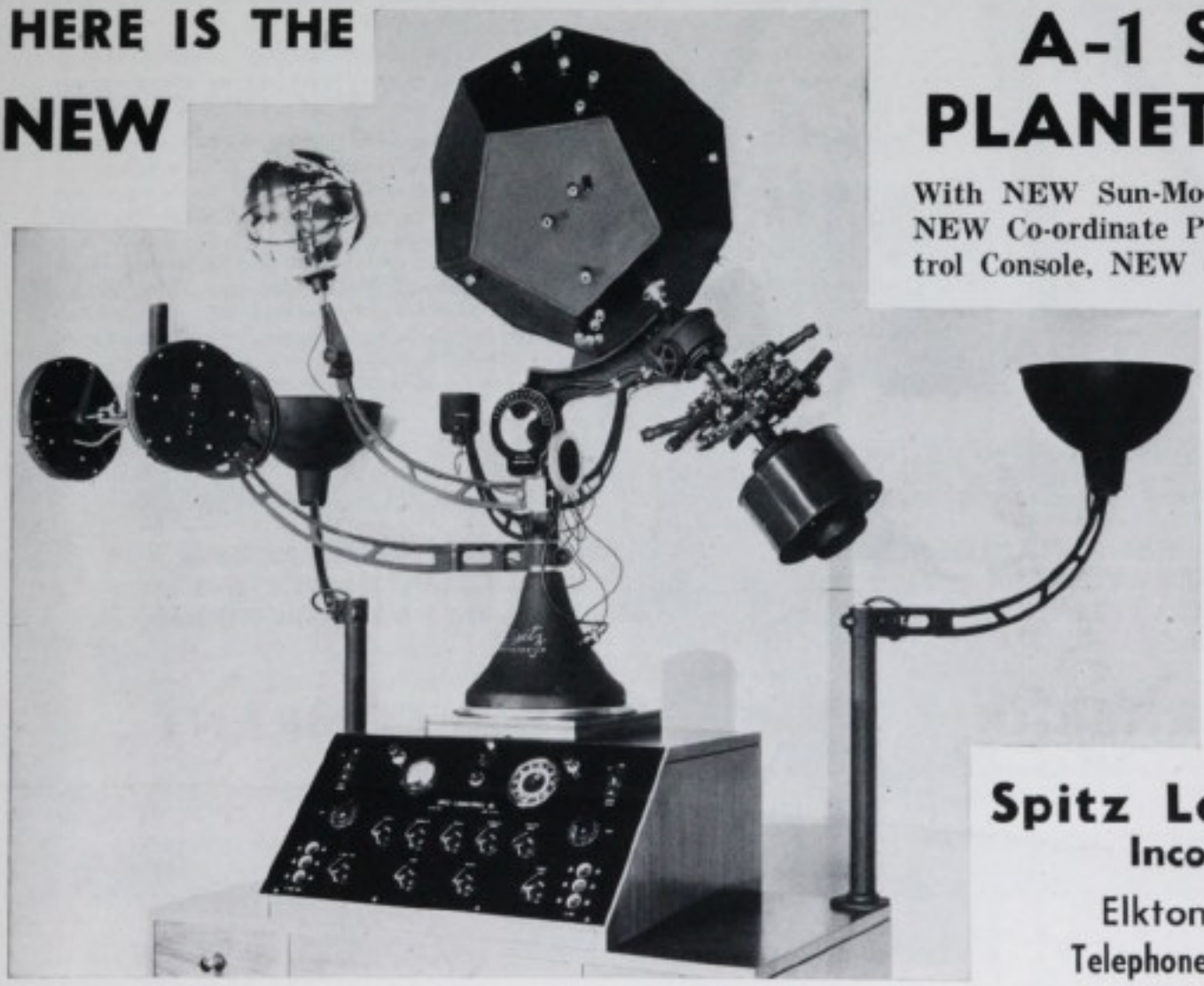

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EDITED BY EARLE B. BROWN

A Telescope Drive with a Right-Ascension Circle

SEVERAL YEARS AGO, when I decided to build a drive for my 8-inch telescope, I discovered that information on this subject is not abundant. I wrote a number of letters, made a few blunders, but finally finished the drive, which is described in this article.

A clock drive is very useful if you anticipate many visitors to your observatory, for with its aid you can follow objects without intervening every few minutes to keep the telescope tracking. In regular observing, high powers are difficult to use without a clock drive, for here especially the apparent motion of the stars is a nuisance. If your telescope is equipped with a right-ascension circle in combination with the clock drive, you will easily be able to find objects from their known positions in the sky.

Drives may be attached to portable telescopes, but their use is more limited since the mounting will not usually be accurately lined up with the celestial pole. A number of ingenious drives have been devised from alarm clocks. In most cases, the clock merely controls the power furnished by a weight or spring. Other portable telescopes have actually used synchronous motors, either with a battery and inverter or with extension cords attached to available sources of power.

With a permanent mounting, a small synchronous motor provides an accurate and convenient drive. These are generally available with built-in gear reductions to about one revolution per minute (1 r.p.m.). The R. W. Cramer Co., Centerbrook, Conn., supplies a small motor (type SX) in a large selection of slow output speeds, as well as a somewhat heavier chart drive motor (type CX) with the final reduction train set at a 15-inch-pound torque.

Many amateurs have found the heavy Telechron motors satisfactory, from the General Electric Co., Ashland, Mass. Their styles C5 and C5M are heavier than ordinary clock motors, developing more than enough torque for a well-balanced telescope. The Telechron C5X is reversible, as are the more expensive K-type synchronous motors manufactured by the Bodine Electric Co., 2254 W. Ohio St., Chicago 12, Ill. Somewhat heavier motors, series PYAZ, may be obtained from the Barber-Coleman Co., Rockford, Ill.

In using a 1-r.p.m. motor, a further reduction of 1,440 to 1 is necessary. Most of this should be done with a large gear on the polar axis. I learned from practical experience that a large worm gear was necessary to eliminate backlash, which was otherwise quite annoying. Worm gears with 100 teeth (which I finally used) are regularly stocked by the Boston Gear Works and Chicago Gear Works, and larger sizes can be made up to order.

The remainder of the reduction can be done with spur gears. "Change" gears of 20 pitch are stocked with every number of teeth from 20 to 120, and some smaller sizes are available. The pitch equals the number of teeth divided by the

Owen Gingerich and his 8-inch f/6.7 Newtonian telescope.

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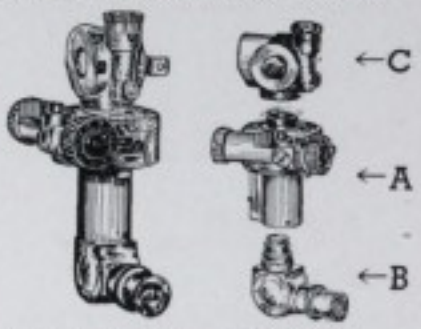

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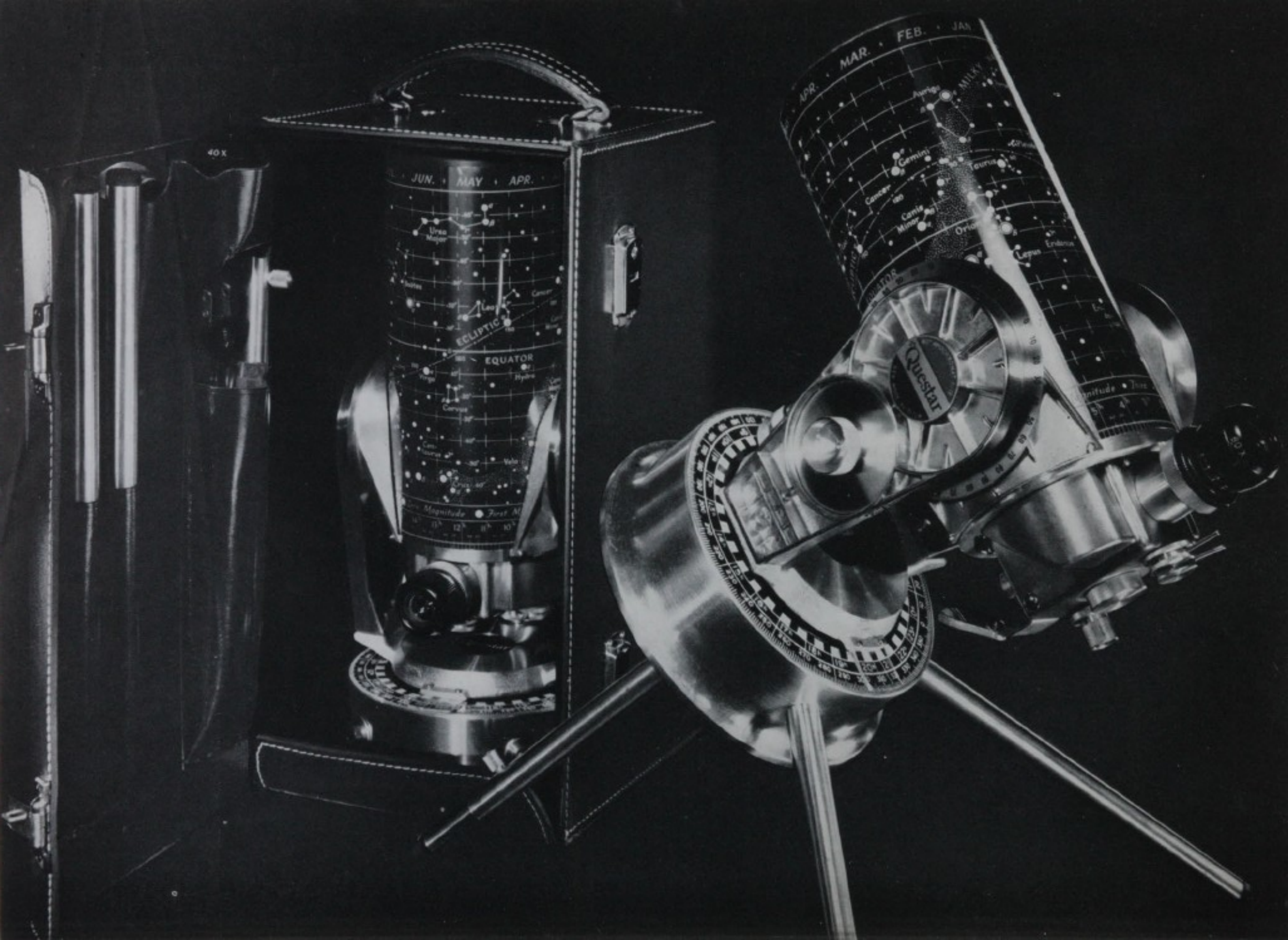
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diameter. Thus, a 20-pitch gear with a diameter of one inch has 20 teeth, while a 32-pitch gear of the same size would have 32 teeth, and so on. There is no objection to using gears with somewhat higher pitch than 20, but the variety is not as great.

Assuming a 100-tooth worm gear on the polar axis, a reduction of 14.4 to 1 is still needed with the spur gears. This can be done in a number of ways: 12- and 15-tooth gears meshing against 36- and 72-tooth gears will do the trick. To check, write

$$\frac{36 \times 72 \times 100}{12 \times 15 \times 1} = 1{,}440.$$

The 12- and 15-tooth gears and the worm are in each case on the driving side of the pair.

Incidentally, worm gears and some of the synchronous motors are available in both right- and left-hand drives; be sure to check the direction of the system. Also, many motors can be obtained in slower speeds. Thus, with a motor of one revolution per hour, the additional reduction need be only 24 to 1, the slower motor already providing a factor of 60 to 1 over the 1-r.p.m. motor. A pair of spurs of 50 and 12 teeth with the 100-tooth worm gear will complete the system.

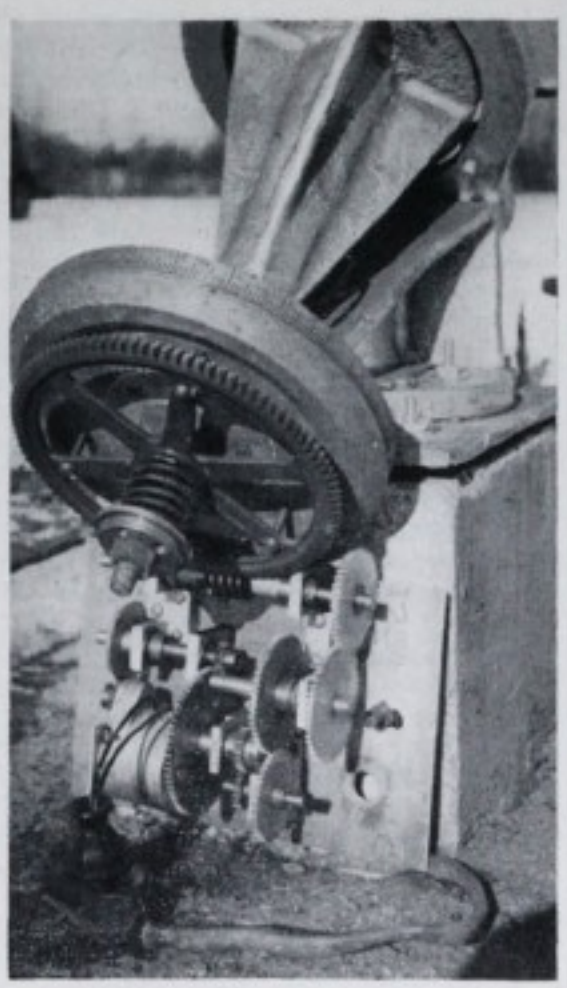
The foregoing calculations apply for a solar day, that is, for following the sun, rather than for a sidereal day, for following the stars. The latter is three minutes 56 seconds shorter than the solar day, and the ratio of 1,440 to 1 should be 1,436.-0667 to 1 for stars. The difference is so small, however, that it would take 12 hours for stars to drift across a typical half-degree field of a telescope with a solar drive. For such precise work as photography, the telescope must be guided regardless of the rate of the drive; thus, there are valid reasons for not going to the trouble of computing for the sidereal rate.

Another factor entering the problem is refraction by the atmosphere, which is greatest near the horizon and least at the zenith. It has the effect of changing the apparent motion of the star across the sky. Let us choose a compromise value for the retardation due to refraction, adding 24 seconds per day for a star on the meridian at the celestial equator. Therefore, the star's sidereal day may be taken to be three minutes 32 seconds shorter than a solar day of 86,400 seconds. This corresponds to a reduction from one r.p.m. of 1,436.4667. A gear combination that is quite close would be expressed by

$$\frac{36 \times 72 \times 28 \times 29 \times 100}{12 \times 15 \times 22 \times 37 \times 1} = 1{,}436.4620$$

This arrangement has the unique feature that by replacing the 29-tooth gear with a 30-tooth gear the drive will be converted very nearly to the lunar rate, enabling the observer readily to follow the moon. Note, however, that when the moon is moving rapidly north or south (near the equinox points in the sky), the eastward motion is slowed considerably. The above system can be somewhat simplified, but the lunar-conversion feature would then be lost.

In my own case, I had available a large number of war-surplus gears that could be assembled about as easily as an Erector



A closeup of the completed drive and right-ascension circle, showing the layout of the gear train, the compression spring, and the 100-tooth worm gear.

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54 mm (2⅛")	680 mm (23½")...	12.50
78 mm (3 1/16")	381 mm (15").....	21.00
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83 mm (3¼")	660 mm (26").....	28.00
83 mm (3¼")	711 mm (28").....	28.00
83 mm (3¼")	876 mm (34½")...	28.00
83 mm (3¼")	1016 mm (40").....	30.00
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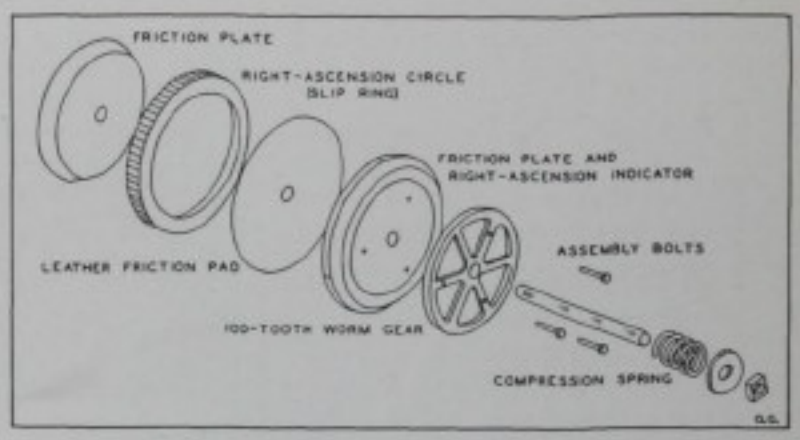
set. The only problem was finding gears in the collection with the appropriate factors. I selected the compromise factor of 1,436.5, suggested by Paul B. Sweger in the February, 1950, **Sky and Telescope** (page 93).



An exploded diagram of the friction clutch and right-ascension circle assembly. Some of the parts may be seen in the photograph on page 435. The outside diameter of the right-ascension circle is about eight inches.

The photograph of the gear train shows the Cramer SX motor, chosen because it is inexpensive (about five dollars) and yet sufficiently powerful. Beginning at the left of the motor, the gears are 20 to 52, 13 to 65, 18 to 17, 40 to 52, 50 to 45. Finally, on the worm gear, the ratio is 1 to 100. This is a 16-pitch bronze worm gear, which cost about nine dollars, including the steel worm.

The plan of the friction clutch and right-ascension circle is illustrated in the drawing. The friction clutch is a crucial part for happy operation of the telescope, and caused some trouble until I arranged the assembly so the spring could be easily adjusted, and added a piece of leather between the cast-aluminum plates. Scrap leather costs about a cent a square inch, and was readily available from a local shoe repair shop.

In operation, the telescope may be freely swung in right ascension, while the drive is working. There is sufficient friction through the leather to hold the telescope steady without clamping. The right-ascension circle turns with the telescope, although it is not fastened rigidly to it. Instead, three small pins with springs set into the first friction plate provide enough friction inside this setting circle ring.

At the beginning of an evening of observation, the right-ascension slip ring must be set by pointing the telescope at a known star, for instance, Vega. Then the circle is slipped around until the chosen indicator on the other friction plate corresponds to the star's right ascension ($18^h\ 35^m.4$ for Vega). Now the instrument is ready for use with any other object for which the right ascension can be obtained, or the right ascension of an object to which the telescope is pointed can be read from the circle. This is because the friction plate with the indicator is bolted onto the worm gear that is driven by the motor and gear train. The indicator slowly moves around during the evening, continually reading right ascension directly and eliminating subtracting for hour-angle determinations.

The mirror is mounted in a cast-iron cell that screws into a ring at the end of the tube. This ring is fastened to the tube structure by three pairs of push-pull screws, some of which can be seen in the picture on page 437, and which provide collimation adjustment. The mirror cell can be screwed off without disturbing the collimation. The ring at the eyepiece end of the tube and the circles are of aluminum; the other castings are iron. The declination circle, made on a dividing head, is graduated

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Looking down on the declination circle and mirror end of the tube.

in degrees. It is read by the light in the small brass tube that is seen in the picture. The two wing nuts on the fork clamp a metal plate against the circle, holding the instrument in declination. These clamps are necessary because the ball bearings on the declination axis permit the tube to swing too freely.

Some amateurs have commented about the center of gravity of the tube being so close to the mirror end. This is easily accomplished by the weight of the iron castings coupled with 20 pounds of lead fastened to the cell. From the standpoint of stability of the eyepiece end, this arrangement is not particularly desirable, but I personally feel that the convenience of the fork mounting compensates for this. All parts of the sky are readily available, and even objects at the zenith can be observed by standing on a single cinder block.

The tube is of channel iron, and its 125-pound total weight contributes to the instrument's stability. The weight is borne by ball bearings on both axes. Four ball-bearing races operate on the polar axis, one large one around the south end of the axis, and three on which the northern part rides. This part of the design, as well as that of the mirror cell, was made by Howard Louth, of Wichita, Kans., who generously donated his patterns to me.

I had trouble with astigmatism until I discovered that the mirror was pinched in the cell. For some time I was bothered with lissajous in the eyepiece, but this trouble was finally traced to the mounting plate that connects the concrete pier and the mounting. A piece of ¼-inch boiler plate, which may be seen in the photograph of the gear train, solved this difficulty.

When the telescope is horizontal, the highest part is only about a yard above the ground, so that it can be covered with a long metal box. The telescope is located at the edge of the campus of Goshen College. This institution has provided the concrete base and an aluminum housing that is easily placed over the instrument. Altogether, the telescope weighs about 200 pounds, and the pier, which goes into the ground about four feet, weighs about 300 pounds.

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2. Is the objective air-spaced or merely cemented?

3. Is a sturdy mounting with slow-motion controls provided?

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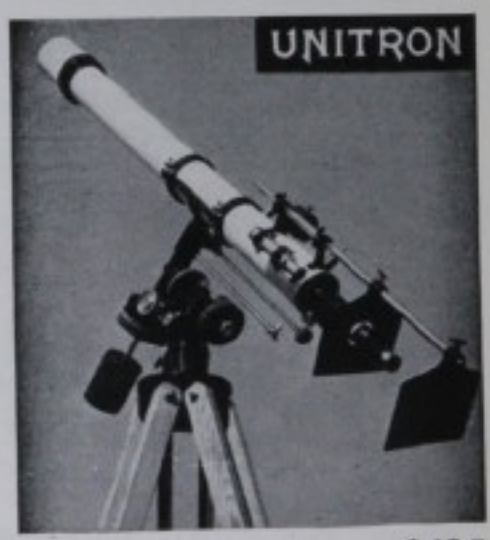

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OBSERVER'S PAGE

Universal time is used unless otherwise noted.

Notes on Observing Venus in the Daytime

SINCE publication in the August issue of the article, "A Naked-eye Method for Finding Venus by Day," by Franklin Miller, Jr., several comments have been received from observers, including the following:

For 60 years, I have had a hobby of finding Venus by day. As a boy, I was fascinated by the brilliant star in the evening sky. As a teen-ager, I would trace and plot its probable path and look for it earlier the next fair day. When it was a morning star, I would follow its course over the roof of the house until 10 or 11 o'clock.

I have seen Venus hundreds of times in the daytime, and many times at midday, often from other places than my home. Here are some selections from my notes:

June 21, 1926. Sunrise at 5:06 daylight saving time. Could see Jupiter clearly at 5:45. Venus easily visible. Mars lost 10 or 15 minutes before sunrise, but not closely followed.

March 11, 1932. Saw planet Venus at 12:30 p.m. after 3 or 4 minutes search about 3° or 4° south of the moon or a bit west of south. Observation by E. W. Moore and Helen D. Wendell.

December 31, 1935. Saw Venus by daylight on 21 mornings, October 21 to December 31.

March 7, 1937. Saw Venus at 1 p.m.; also seen by Mrs. Moore, Helen Moore, and Helen Miles.

E. W. MOORE
93 Judson St.
Malden, Mass.

You scientists certainly make it difficult for us novices. Here I've been watching Venus during the daytime since December, 1949, but along comes Mr. Miller with a scientific method that makes mine entirely obsolete.

For years I have been buying a 35-cent ephemeris, which shows bi-diurnal declinations of the planets, and using the **World Almanac** in order to estimate the time they cross the meridian. I make a cardboard angle to show the altitude of Venus, place it upon the iron plate attached to the axle of my scope, raise the instrument to the proper height, jiggle it a few times, and there is Venus!

When the planet is sufficiently bright, I usually sight it first with my naked eye, and then turn the telescope upon it.

Using your "Predictions of Bright Minor Planet Positions," I followed the tiny planet Vesta from February 1 to April 14, 1952, and Ceres during the second half of November of the same year, with my 3¾-inch refractor. I expect to identify Iris during the next few nights [written August 10th].

W. R. HOWELL
Western Baptist Seminary
2119 Tracy Ave.
Kansas City 8, Mo.

VARIABLE STAR MAXIMA

October 6, R Reticuli, 043263, 7.7; 11, W Lyrae, 181136, 8.0; 14, R Hydrae, 132422, 4.6; 21, R Ursae Majoris, 103769, 7.6; 22, RT Sagittarii, 201139, 7.9; 23, S Pegasi, 231508, 8.0; 24, RV Sagittarii, 182133, 7.8; 26, V Cancri, 081617, 8.0; 30, R Canum Venaticorum, 134440a, 7.7. November 5, S Hydrae, 084803, 7.9; 5, R Aquarii, 233815, 7.3.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude.

FINDING VENUS BY DAY

This ephemeris continues that on page 353 of the August issue, where a detailed explanation was given in the article by Franklin Miller, Jr. Example: Suppose an observer locates Mars, magnitude —0.3, on the evening of October 5th, noting that it is in line with a flagpole or other landmark at, say, 8:00 p.m. Then Venus will be similarly placed with respect to the mark 19 hours 47 minutes later, or at 3:47 p.m. on October 6th. The difference in declination between Venus and the finder object is always less than about two degrees; the letter N means that Venus will be slightly farther north than the object.

Because of the paucity of bright stars in this part of the evening sky, it has been necessary to choose Point **A**, which is situated three degrees north of the 1st-magnitude star Fomalhaut, in Piscis Austrinus.

Mars, —0.3: Oct. 1, 19:48, N; 2, 19:48, N; 3, 19:48, N; 4, 19:48, N; 5, 19:47, N; 6, 19:47, N; 7, 19:47, N; 8, 19:47; 9, 19:46, S; 10, 19:45, S; 11, 19:45, S; 12, 19:44, S; 13, 19:42, S; 14, 19:41, S.

Point **A**: Oct. 15, 16:42, N; 16, 16:43, N; 17, 16:44, N; 18, 16:45, N; 19, 16:46, N; 20, 16:47, N; 21, 16:47, N; 22, 16:48, N; 23, 16:48, N; 24, 16:48, N; 25, 16:48, N; 26, 16:47, N; 27, 16:47, N; 28, 16:46, N; 29, 16:46, N; 30, 16:45, N; 31, 16:44, N. Nov. 1, 16:42, N; 2, 16:41, N; 3, 16:39, N; 4, 16:38, N; 5, 16:36, N.

PREDICTIONS OF BRIGHT MINOR PLANET POSITIONS

Fides, 37, 9.4. Oct. 5, 2:33.0 +16-58; 15, 2:26.4 +16-50; 25, 2:17.8 +16-27. Nov. 4, 2:08.4 +15-57; 14, 1:59.7 +15-24; 24, 1:52.9 +14-58.

Bellona, 28, 9.7. Oct. 25, 4:09.8 +6-32. Nov. 4, 4:03.7 +5-41; 14, 3:55.7 +4-57; 24, 3:46.8 +4-25. Dec. 4, 3:38.0 +4-09; 14, 3:30.4 +4-14.

After the asteroid's name are its number and the magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1954.0) for 0h Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

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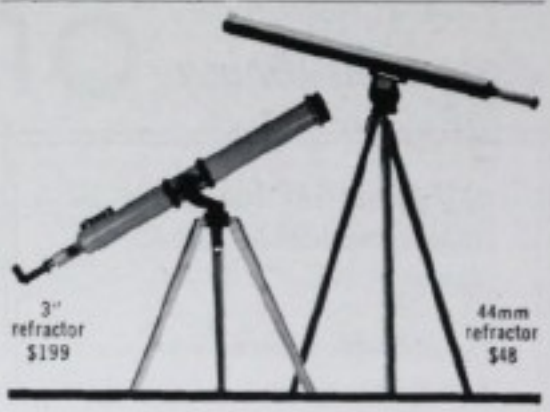

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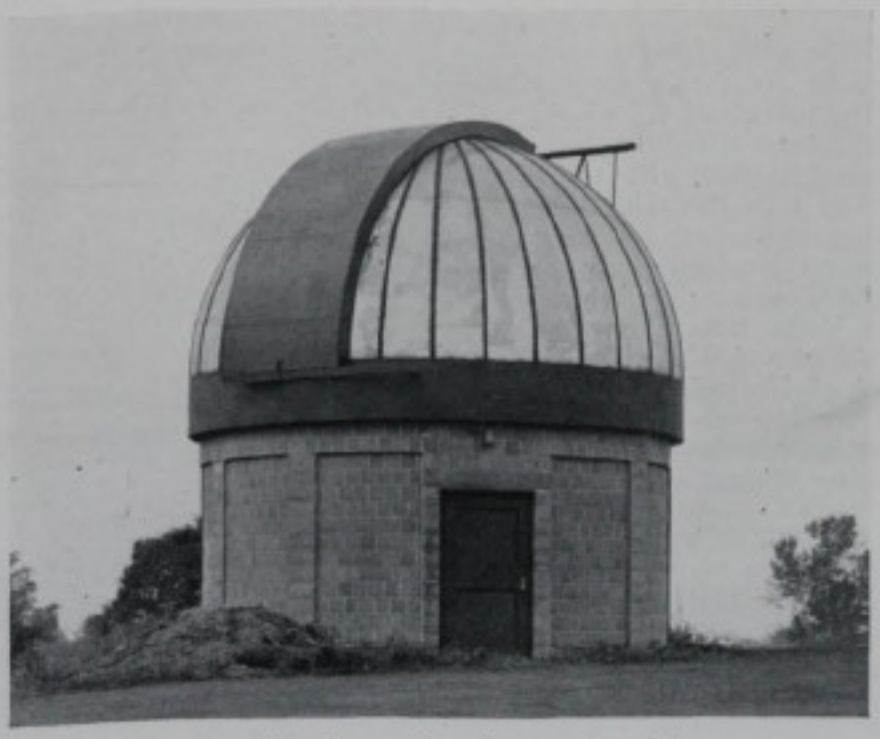

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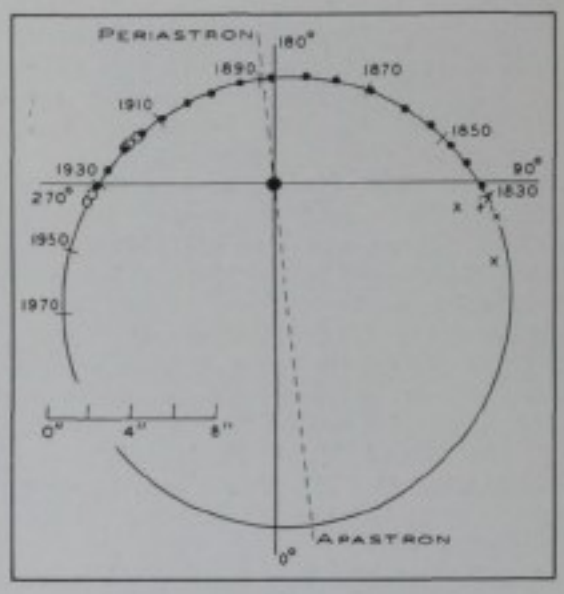
DEEP-SKY WONDERS

SITUATED between α and γ in the familiar "W" of Cassiopeia, the bright binary η Cassiopeiae (ADS 671) can easily be found without special charts, and should be familiar to all star lovers. This famous double star was discovered by the elder Herschel on August 17, 1779, and ever since it has been a favorite of observers with small telescopes, in which it is easily resolved. It is located at 0^h $46^m.1$, $+57°$ 33' (1950). The magnitudes of the two components are 3.7 and 7.5, and the stars are now 10".6 apart.

The color contrast in this pair is beautiful, as one might anticipate from the spectral types of the stars, F8 and M1. Admiral Smyth called them "pale white and purple," his son Piazzi Smyth indicated "yellow and Indian red," and Barnes wrote "gold and orange red."



K. A. Strand's 526-year orbit of Eta Cassiopeiae. Dots denote positions of the companion from visual observations; circles, photographic measures; and crosses, unreliable early visual data.

Many orbits have been computed for this long-period binary, with periods ranging from 700 to 167 years, even though the elements are still nearly indeterminate. Probably the best of the recent solutions is that of Strand (1937), which gives 526 years. According to Strand, whose plot is reproduced here, the separation varies between 5", in 1890, and 16", which will be reached about 2152.

Thus η Cassiopeiae is always within reach of a 3-inch telescope. Small reflectors may give some trouble if the companion falls on the diffraction flare of a diagonal. The remedy here is to use a circular prism support, or to rotate the tube in its cradle to make the companion fall in a clear area. The writer would be interested to get a post card telling how small a telescope will still show the companion; test by masking down the objective until the faint star no longer shows.

WALTER SCOTT HOUSTON

UNIVERSAL TIME (UT)

TIMES used on the Observer's Page are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, and the result is your standard time on the day preceding the Greenwich date shown.

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SUNSPOT NUMBERS

July 1-2, 0, 0; **3,** 0, 8; **4-7,** 0, 0; **8,** 5, 7; **9,** 1, 0; **10-11,** 0, 0; **12,** 4, 7; **13,** 10, 10; **14,** 9, 15; **15,** 5, 8; **16,** 5, 15; **17,** 8, 7; **18,** 3, 7; **19-23,** 0, 0; **24,** 3, 8; **25,** 7, 10; **26,** 3, 7; **27,** 0, 0; **28,** 0, 10; **29,** 0, 7; **30,** 1, 7; **31,** 0, 6. Means for July: 2.1 American; 4.5 Zurich.

Above are given the date, the American number, then the Zurich number. These are observed mean relative sunspot numbers, the American computed by D. W. Rosebrugh from AAVSO Solar Division observations, the Zurich numbers from Zurich Observatory and its stations in Locarno and Arosa.

OCCULTATION PREDICTIONS

October 6-7 **Rho Capricorni** 5.0, 20:26.2 −17-58.0, 10, Im: **A** 1:34.9 ... ... 122; **B** 1:26.5 −2.4 −1.2 109; **C** 1:27.3 ... ... 122; **D** 1:14.2 −2.4 −0.7 103; **E** 0:47.2 −2.3 +0.3 93; **F** 0:27.3 −2.7 +0.1 103.

October 20-21 **Pi Leonis** 4.9, 9:57.8 +8-15.9, 24, Em: **C** 10:13.4 −0.6 −3.1 352; **E** 10:00.9 −0.6 −2.4 347; **F** 10:05.5 −0.8 −0.3 306.

November 12-13 **1 Geminorum** 4.3, 6:01.3 +23-16.1, 18, Im: **B** 11:09.2 −0.3 −2.3 135; **D** 11:12.7 −0.1 −3.0 149.

For stations in the United States and Canada, usually for stars of magnitude 5.0 or brighter, data from the **American Ephemeris** and the **British Nautical Almanac** are given here, as follows: evening-morning date, star name, magnitude, right ascension in hours and minutes, declination in degrees and minutes, moon's age in days, immersion or emersion; standard station designation, UT, **a** and **b** quantities in minutes, position angle on the moon's limb; the same data for each standard station westward.

The **a** and **b** quantities tabulated in each case are variations of standard-station predicted times per degree of longitude and of latitude, respectively, enabling computation of fairly accurate times for one's local station (long. **Lo,** lat. **L**) within 200 or 300 miles of a standard station (long. **LoS,** lat. **LS**). Multiply **a** by the difference in longitude (**Lo** — **LoS**), and multiply **b** by the difference in latitude (**L** — **LS**), with due regard to arithmetic signs, and add both results to (or subtract from, as the case may be) the standard-station predicted time to obtain time at the local station. Then convert the Universal time to your standard time.

Longitudes and latitudes of standard stations are:

A	+72°.5,	+42°.5	**E**	+91°.0,	+40°.0
B	+73°.6,	+45°.5	**F**	+98°.0,	+31°.0
C	+77°.1,	+38°.9	**G**	Discontinued	
D	+79°.4,	+43°.7	**H**	+120°.0,	+36°.0
			I	+123°.1,	+49°.5

MINIMA OF ALGOL

October 2, 13:40; 5, 10:29; 8, 7:18; 11, 4:07; 14, 0:56; 16, 21:45; 19, 18:33; 22, 15:21; 25, 12:10; 28, 8:59; 31, 5:48. November 3, 2:37; 5, 23:26; 8, 20:15.

These minima predictions for Algol are based on the formula in the 1953 **International Supplement** of the Cracow Observatory. The times given are geocentric; they can be compared directly with observations.

OCTOBER METEORS

The Orionid meteor stream, one of the better annual showers, comes to maximum on October 19-20. Rates of 20 meteors per hour are predicted under good conditions after midnight. The moon is at last quarter on the 18th, and will not seriously interfere with observations. Orionids are typically swift, radiating from a point about 10° northeast of Betelgeuse.

Another meteor shower, the Taurids, may be observed during late October, reaching maximum the first 10 days of November. These meteors are slow moving and about six per hour may be expected.

E. O.

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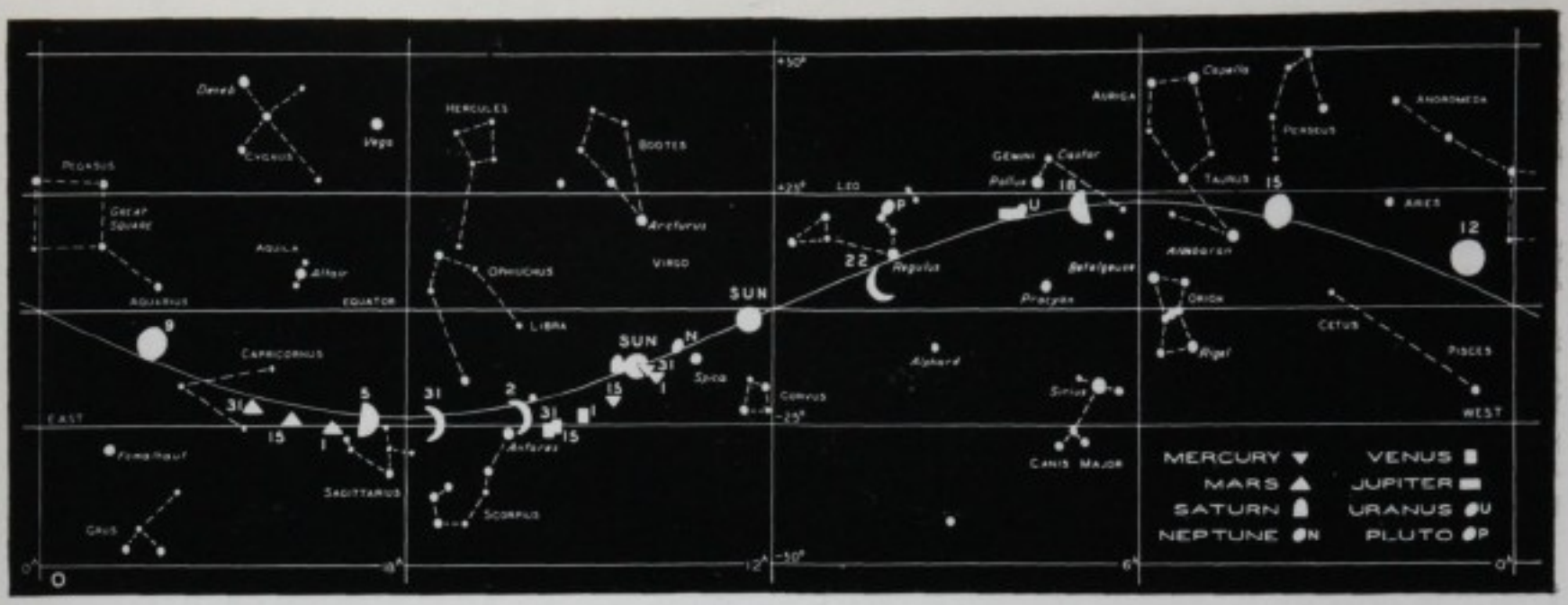

THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month and for other dates shown.

Mercury attains greatest elongation on October 6th, 25° 32′ east of the sun, but will be a difficult object to view. It sets less than an hour after the sun, at magnitude +0.3.

Venus, at the climax of its current appearance in the evening sky, reaches greatest brilliance on the 11th, at magnitude —4.3. Unfortunately for observers in northern latitudes, the planet is located about 20° south of the sun in declination and sets about 1¼ hours after sunset on the 11th. The planet may be viewed until the end of the month, then setting half an hour after the sun and slightly fainter, at —4.0. On the 11th, Venus appears as a crescent, 40″ in diameter, with 26 per cent of its disk illuminated. A neutral-density filter may be of aid in observing Venus, because of its brilliance.

Mars continues its rapid eastward motion, crossing from Sagittarius to Capricornus during the month. Eastern quadrature with the sun occurs on October 28th, when the planet sets nearly six hours after the sun, appearing at magnitude 0. The Martian disk is 10″ in diameter on the 24th and appears slightly gibbous, for 85 per cent of the disk is illuminated as seen from the earth.

Jupiter moves from Gemini into Cancer early in the month. Western quadrature occurs on October 22nd, the planet then rising 5½ hours after sunset. Jupiter shines at magnitude —1.8, presenting an equatorial diameter of 37″.6, on the 15th. The first of a series of three conjunctions with Uranus occurs on the 8th, with Jupiter passing 21′ south.

Saturn vanishes into the sun's glare in mid-October. On the 9th, Saturn will be 5° 34′ north of Mercury, but one must have a clear southwest horizon to see this conjunction.

Uranus, as noted above, will be 21′ north of Jupiter on the 8th, and there should be no difficulty in identifying Uranus with slight optical aid, as no 6th-magnitude star is near by.

Neptune is invisible. It enters the morning sky on October 19th, following its conjunction with the sun.

E. O.

MOON PHASES AND DISTANCE

First quarter	October	5, 5:31
Full moon	October	12, 5:10
Last quarter	October	18, 20:30
New moon	October	26, 17:47
First quarter	November	3, 20:55

		Distance	Diameter
October			
Perigee	13, 2h	222,500 mi.	33′ 22″
Apogee	27, 23h	252,600 mi.	29′ 23″
November			
Perigee	10, 13h	221,500 mi.	33′ 31″

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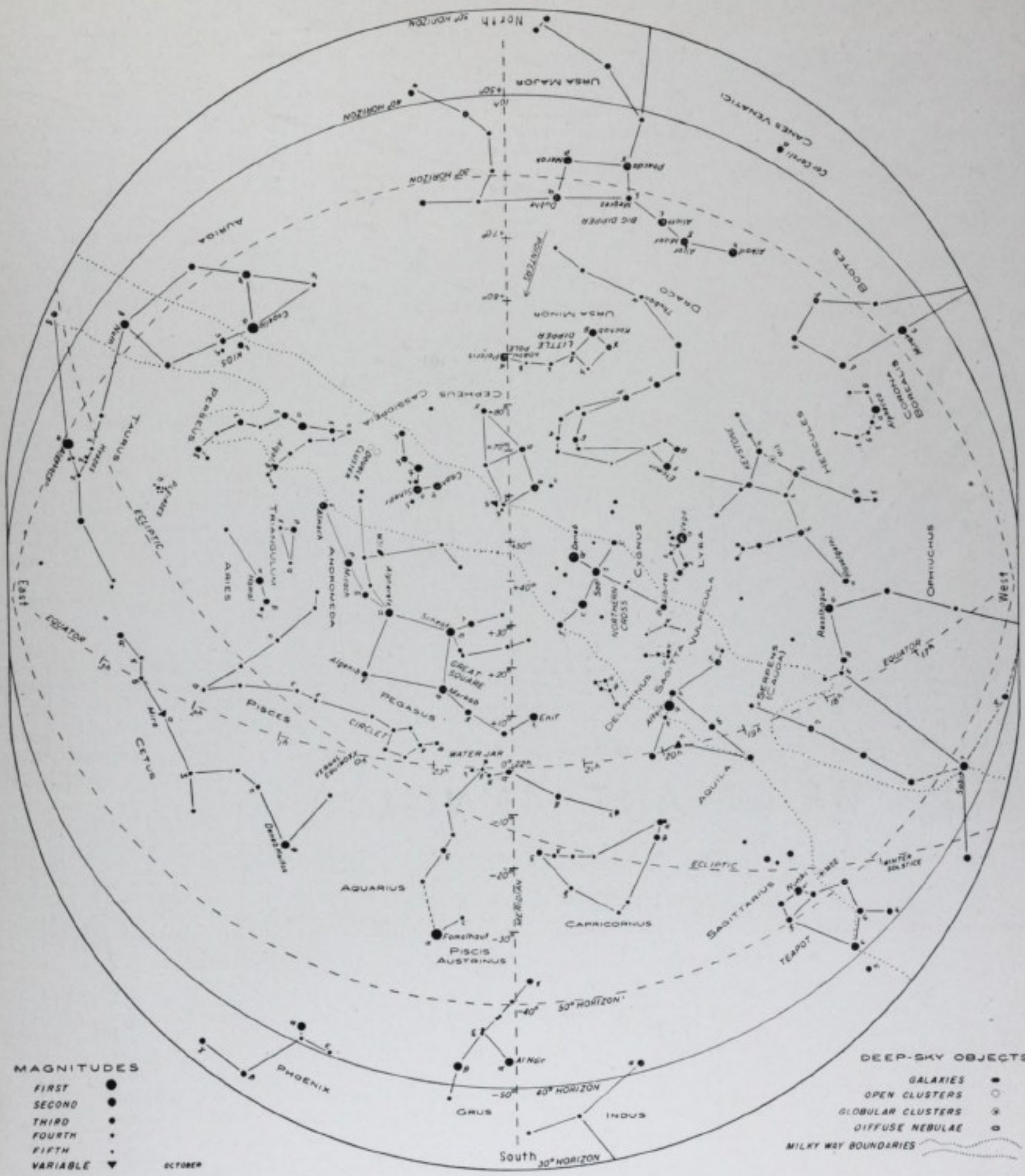

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of October, respectively.

STARS FOR OCTOBER

AS SUMMER fades into fall, the constellation of Pegasus, the Winged Horse, is again conspicuous high in the southern sky at chart time. This is one of the easiest of the constellations for the beginner to identify, because of the four bright stars that form the Great Square of Pegasus.

Alpheratz, at the northeastern corner of the square, officially belongs to the constellation of Andromeda. When Bayer assigned Greek letters to the stars, at the beginning of the 17th century, he called this star Alpha Andromedae and Delta Pegasi, but the latter designation has fallen into disuse. There is thus no star labeled δ in the constellation of Pegasus on modern star charts.

The horse is upside down in our northern sky, with only his foreparts shown. The bright star Enif (Epsilon) is in his nose, and his forefeet may be traced by stars extending from the northwestern corner of the Great Square.

The familiar W-shaped group of Cassiopeia is prominent in the northeast at this time. Gamma Cassiopeiae has had a curious history. For many years it was the brightest star in the constellation, at magnitude 2.2. In the summer of 1936 it began without warning to brighten, and by the spring of 1937 it had become 1.6, a match for Castor. A decline then set in, and since 1939 Gamma has been about magnitude 2.7, definitely fainter than Alpha and Beta, and only slightly brighter than Delta.

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See pages 438 and 442 for catalog information, terms, and photographs of UNITRON Refractors.

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